CASHEW
Research and Development

Proceedings of the International Cashew Symposium
Cochin, Kerala, India
(12–15 March, 1979)

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Foreword

The first International Cashew Symposium held at Cochin in 1979 was a worldwide recognition of the importance this crop has obtained in the second half of this century. This statement was underlined by the co-operation between the Indian Council of Agricultural Research, the Indian Society for Plantation Crops and the International Society for Horticultural Sciences in the organization of this symposium.

Lack of communication between the various countries where research on cashew was undertaken resulted in complete overlapping of research programmes in some fields and almost no research in other aspects of this crop. Only an effective exchange of information between the various research institutes could improve this situation.

The papers read during the symposium were of great value and many delegates were surprised by the number of countries where research on cashew is going on and by the importance of its cultivation in these countries. Apart from the official programme, the delegates benefited very much from the direct contact with colleagues from other countries. Discussions before and after the sessions were as animated as the discussions during the sessions, and it may be assumed that the symposium has achieved its goal.

I have no doubt that I speak in name of all participants when I express our feelings of great thankfulness for the great hospitality we have received in Cochin, for the perfect organization, and for all the efforts made to make this meeting as fruitful and pleasant as possible. We all hope that this symposium will be followed by a second one. Which country would accept the challenge?

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J.G. Ohler

Preface

Tree nuts have been one of the oldest sources of food for man. Cashew (*Anacardium occidentale* L.) leads them in world production with 450,000 tons raw nuts and ranks third in the international trade after hazel nuts and almonds. Cashew is indigenous to South America. The Portuguese brought it into India during the 16th century; from India it is believed to have spread to other tropical countries. India, Tanzania and Mozambique are the leading producers of raw cashewnuts. Though export figures fluctuate widely from year to year, India exports about 32,000 tons processed nuts annually earning over 1,300 million rupees every year. Dwindling export share consequent to development of processing facilities in other countries and increasing competition from other nut crops like macadamia were of great concern to the Indian Cashew Industry.

Cashew research in India dates back to 1950's when Indian Council of Agricultural Research sanctioned ad hoc schemes in the then composite Madras, Travancore, Cochin and Bombay States. Thus Kottarakkara (Kerala) in 1952; Ullal (Karnataka in 1953 and Vengurla (Maharastra) in 1957 came into being as pioneering cashew centres in the country. More research schemes were started with ICAR's assistance in 1955 at Bapatla (Andhra Pradesh) and in 1956 at Deragaon (now shifted to Kothiali) in Assam. During the period Central Food Technological Research Institute, Mysore and National Chemical Laboratory, Pune were also engaged in developing technologies for economic utilisation of cashew apple and Cashew Nut-Shell Liquid (CNSL). In the second phase of strengthening cashew research in India, the ICAR started All India Spices and Cashewnut Improvement Project in 1971 linking different research centres in the country as a network. Collection, conservation and evaluation of germplasm, hybridization and selection, vegetative propagation, and nutritional studies were the primary areas under this programme.

Research on cashew in other parts of the world has been fragmentary. However, considerable interest in this crop had been evinced of late by a number of countries. To take stock of the situation and plan future research and development work, an International Cashew Symposium was jointly organised by the Indian Council of Agricultural Research, Indian Society for Plantation Crops and the International Society for Horticultural Sciences for the first time in the world during March, 1979 at Cochin, Kerala, India. The Films Division of Government of India brought out a special film to commemorate the first International Cashew Symposium. A monograph on cashew and a bibliography on cashew work in India were also released.

This book "Cashew Research and Development" contains papers presented in six sessions, both as oral and poster presentations. In addition Status Reports on Cashew Genetic Resources from India, Sri Lanka, Malaysia, Philippines and Australia also find a place in this book. The session on vegetative propagation contains invited papers covering the work done in India from the inception of cashew research.

A total of 216 delegates from India, Indonesia, Malaysia, Sri Lanka, Philippines, Kenya, Zambia, Suriname, England, The Netherlands, Switzerland, Australia, Italy, Spain, and Food and Agricultural Organisation, Rome, participated in the four day deliberations.

The financial assistance given by the Government of Kerala, Karnataka Horticultural Department, Cashew Corporation of India, Konkan Krishi Vidyapeeth, Council of Scientific and Industrial Research, Agricultural Department of Tamil Nadu, Orissa Forest Department, Andhra Pradesh Agricultural University and Karnataka Cashew Corporation is gratefully acknowledged.

The successful conduct of the Symposium was possible due to the initiative and inspiration given by Dr. M.S. Swaminathan, then Director General of ICAR, and Dr. N.M. Nayar, former Director of Central Plantation Crops Research Institute, who, as Organising Committee and Programme Committee Chairman, has shouldered the entire responsibility to conduct this Symposium in India. Special mention need to be made of Mr. J.G. Ohler, Royal Tropical Institute, who was instrumental to the idea of organising an international cashew symposium in India.

K.V. AHAMED BAVAPPA
President
Indian Society for Plantation Crops

Kasaragod, India
19–11–1984

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KEYNOTE ADDRESS

by

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Cashew, *Anacardium occidentale,* leads the edible nuts in international trade with 20 per cent of the market after hazelnuts (29%), and almonds (21%). From tropical America, its natural habitat, it was spread throughout the tropics by the early Portuguese and Spanish travellers. However, cashew nut gained importance in international trade only in the early 1920's. Today, it is cultivated mainly in India, Mozambique, Tanzania, Brazil, and Kenya. The total annual world production is estimated to be about 570,000 tons. The area under cashew in India in 1976-77 was estimated to be 423,000 ha with a production of 179,000 tons raw nuts.

We, in India, have been discussing for some years now the problems of our cashew industry arising out of a shortage of nuts in the international market for import for processing. The situation arose because, until recently, most of the cashewnut produced in the world was being processed using the finger skills of rural women and men of Kerala State. With increasing mechanisation in processing in the countries from where we have been importing raw nuts, India has been finding it difficult to give full employment to the labour which has been engaged in cashew processing until now. It is not my intention to dwell upon this aspect of the cashew problem in this Symposium. I shall restrict the present discussion to analysing the yield potential of the cashew plant in relation to the yields currently being obtained in India with a view to stimulating an in depth discussion of methods for increasing the production and productivity of this crop.

Potential for Yield

We do not have data on indices like photosynthetic efficiency, total dry matter production, and the manner of partitioning of total dry matter. It is also not clear whether cashew has the C–3 or C–4 pathway of photosynthesis. Hence, the calculation of yield potential has to be tentative and somewhat speculative. The highest reported annual yield of a cashewnut tree in India is 125 kg of raw nuts from Kottarakkara in Kerala. A high yielding tree (Tree No. 129) at Bapatla has recorded yields above 90 kg in one season, with an average yield of 73 kg raw nuts over 8-10 years. This would work out to

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an yield of 14.6 tons of raw nuts assuming a population of 200 trees per hectare. There is some arbitrariness in this kind of extrapolation because the vegetative growth, and consequently, the utilisation of solar energy and soil nutrients will depend upon plant population. Hence, the average productivity per hectare will be less than the projections made from yield records of individual trees. The average yields obtained in different States, and the yields obtained at the Cashew Research Stations in each State together with the yields obtained by farmers in minikit trials are presented in the following table:

	Yield of raw nuts, tons/ha		
	Research farm	*Farmers' field*	*State average*
Kerala (Anakkayam)	5.2	2.20	1.09
Maharashtra (Vengurla)	3.0	0.10	0.05
Tamil Nadu (Vridhachalam)	2.8	0.38	0.12
Andhra Pradesh (Bapatla)	2.8	1.20	0.40

If we regard the mean yield of tree No. 129 at Bapatla over the past ten years as a realisable yield goal, the gap between what may be achieved (14.6 tons/ha) and the average yields obtained at research station (2.8-5.2 tons/ha) is quite wide, the ratio varying from 5.2:1 for Bapatla to 2.8:1 for Kerala. This is *a Research Gap* which can be filled only through intensive interdisciplinary research effort. We may refer to this as Gap I.

The gap between the best yield obtained in research farms and that obtained by a good farmer can be referred to as Gap II, or a *Research cum Management Gap*. This will need attention both from research and extension workers. The ratio between research farm yields and good farmers' yields varies from 30:1 in Maharashtra to less than 3:1 in Kerala and Andhra Pradesh. If we analyse the data from the research farms, we will notice that the research *cum* management gap is mainly due to the genetic superiority of the planting material used in the research farms and better management consisting of regular fertilizer application and timely pest control measures.

The gap between the best average yield realised by a good farmer in the State and the State average can be referred to as Gap III or an *Extension cum Management cum Resources Gap*. This is a gap which can be bridged immediately, provided there is a concerted effort by development, extension, and research agencies. The ratio between a good farmer's yield and the State average varies only between 2 and 3 in different States, though the State average as well as yields in farmers' plots vary widely among the States. In the context of the need for an immediate stepping up of production, it is this gap which will need maximum attention.

An aspect which requires our special attention in this regard is the difference in average yields between Kerala and other States. The figure of 1.1 tons/ha for Kerala may appear to be on the higher side when taken on a plantation scale. This needs to be looked into. On the other hand, the figures for Maharashtra seem to be under-estimates, because in Maharashtra average yields are probably computed from the actual quantity of raw nuts collected from the State and dividing it by the area believed to have been planted. Area estimates present many difficulties, since cashew plantations may be interplanted with other trees and crops. There is need for more statistical work on area and yield estimates in cashew.

While discussing the yield potential in different cashew growing tracts, the variation in agroclimatic factors should also be taken into consideration. The variation in the quantity and distribution of annual rainfall may not affect the yields of cashew in a heavy rainfall area like Kerala as much as in other States like Tamil Nadu and Andhra Pradesh, which receive much less rainfall.

While assessing the role of management practices, it should be recognised that the potential for increasing yields by fertilizer application will depend on the availability of soil water. The potential for increasing yields through fertilizer application will be more in the west coast than on the east coast of India under rainfed conditions. If, however, suitable water-harvesting techniques are introduced, it may be possible to provide adequate nutrients.

Major Problems

The major constraints in increasing the production and productivity of cashew in India were discussed at a National Seminar on Cashew Production at Ernakulam held on 15th September 1976.

1. **Ecological**

Cashew was introduced into the country by the Portuguese on the west coast mainly as a soil binding crop. Most of the existing crop in the country until recently was self-sown on forest lands and marginal lands which could not be utilised profitably for other plantation crops or field crops. With increasing pressure on land, it seems unlikely that cashew will be cultivated on better classes of land in the near future, unless it can be demonstrated that this crop can give more income per hectare than the alternatives available. There is thus the inherent limitation that we are cultivating cashew on poor soils on steep slopes on the west coast and in sandy areas on the east coast where intensive management like intercultivation and manuring are seldom applied.

2. Technological

2.1. *Non-availability of high yielding varieties and selections.* It is only recently that we have been able to release high yielding selections/hybrids for distribution to the cultivators. Even today, there are very few seed gardens from where quality planting material is available to the farmers. In a cross pollinated crop like cashew, we should ideally have successful vegetative propagation techniques to ensure uniformly high yields of new plantations. However, our success with these methods has been limited. Even where success has been claimed in experimental stations, field establishment on a large scale has not been achieved, and we are yet to have progeny-tested high yielding mother trees in large numbers for the collection and distribution of clonal seeds among the cultivators.

2.2. *Nutrition.* It is a safe assumption that only a few farmers apply fertilizers regularly. Soil health care has received very little attention, although cashew itself was introduced for conserving the soil. Our fertilizer recommendations are yet arbitrary. Fertilizer experiments have been laid out only very recently and hence results which can be made use of in recommending fertilizer schedules for different soils in different tracts of the country are yet to become available, for making location specific recommendations.

2.3. *Pest Control.* It has been possible to identify the major pests attacking the crop. The one that needs maximum attention is the tea mosquito, which in severe cases of infestation, causes upto 30 per cent loss of crops on the west coast of India. Good control measures have been developed against this pest by the Central Plantation Crops Research Institute, Kasaragod. However, what is lacking is a co-ordinated effort to adopt the crop protection measures required throughout the infested areas during the flowering season for controlling the pest. There exists primarily an organisational gap in making the small cultivators aware of the problem. Further, the non-availability of equipment and credit to the farmers for adopting plant protection measures like aerial spraying on a community basis is a major problem.

3. Socio-economic Constraints

We are fortunate that there are very few social constraints limiting the production of cashew in India. There is hence a great pressure on the research community and the farmers to increase the production and productivity, because a majority of the labourers employed in cashew processing factories will be put to much hardship if the processing factories do not work to full capacity. It is also necessary to reduce the cost of production of both raw and processed cashew nut in the country so that our prices will be competitive in the international market. The cost of production in India is much higher than in other countries. From the cost of cultivation, we find that considerable savings could be made in the future if the tea mosquito is eliminated for ever as a serious pest.

There is a very good case to assure the farmers a minimum support price on a long term basis, like say 5-8 years, so that they will be able to invest in permanent improvements like replanting with improved cultivars, manuring, and so on. Also, this will provide the incentive to invest in new plantations which will take 8-10 years to return the investment.

We should also evolve technology to make better use of cashew apple which is at present utilised on a commercial scale only in Goa. Another approach for assuring a steady income for cashew farmers would be to popularise mixed cropping of cashew, casuarina, and coconut in sandy belts which has been shown to be successful in Orissa.

Among the major blessings of the cashew industry in India are: (a) absence of any serious disease problems, and (b) availability of technology, the required skilled labour force, and necessary processing capacity to handle nearly three times the present production. Also, there seems to be no imminent danger of a fall in demand or over production. The world requirement of cashew kernel is projected at 235,000 tons in 1980 which is twice as much as the present availability.

With several short and long term measures receiving priority attention from the Government of India during the Sixth Plan, we hope to strengthen cashew research and development in India with the launching of a Multi State Cashew Project, which includes the establishment of a National Cashew Research Centre.

International Action

There is need at the international level for establishing a germplasm garden in cashew with genetic material from different parts of the world. This will help to develop an International Cashew Hybridization Garden. Because of its nutritive properties, the home consumption of cashew should be promoted particularly in the producing countries, specially among the economically handicapped sections of the community. There is hence no need to look at cashew only as an export crop, with different countries having competitive interests. Kerala will be ideally suited for establishing a Global Germplasm Nursery, where valuable genetic material can be preserved for current use as well as for posterity.

Another area of intensive inter-disciplinary research which needs attention is production physiology. The input-output energy conversion efficiency needs to be studied.

I hope as a result of this International Symposium, there will be concerted efforts in improving the efficiency of both production and post-harvest technologies, so that more people in the world are able to consume cashewnut.

BOTANY, PHYSIOLOGY AND CROP IMPROVEMENT

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Primary Vascularization in Cashew (*Anacardium occidentale* L.)

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Abstract

In the mature embryo procambium forms a hollow cylinder in the root-hypocotyl axis which is correlated with the tree habit. Prior to germination, protoxylem elements have differentiated not only in the cotyledons and root but also in the hypocotyl and to a certain extent in the epicotyl.

The ontogenetic order of maturation of xylem is first in the cotyledons then in root, and later in the hypocotyl and epicotyl. In the root, the differentiation of protoxylem bundles begin in the oldest part and the pattern of longitudinal differentiation is acropetal. In cotyledons also, a similar pattern of differentiation was noted. Unlike in the root and cotyledons, the differentiation of xylem groups of the hypocotyl does not appear to follow a clear-cut direction of differentiation. The xylem strands of the leaf unites with that of the epicotyl further differentiate basipetally down the cotylendonary mode and join the hypocotylary xylem bundles.

The continuity of the vasculature between root and hypocotyl, and hypocotyl and cotyledons is by a simple process of 'bridging-up'. The mode of transition observed in *Anacardium occidentale* does not correspond with any of the types recorded by Van Tieghem (1891) or Eames and Mac Daniels (1947).

Introduction

The morphological literature of the family Anacardiaceae is well summarised by Srinivasachar (1940) and the embryological literature by Davis (1965). However, no information is available either on the pattern of procambialisation or on the pattern of differentiation of primary xylem and phloem of the embryo and the seedling of this family.

A large amount of data is available on the anatomy of seedlings of different plant species. The work of Van Tieghem (1891), Hill and de Fraine (1913), Compton (1912), Sargant (1902) adopted by Eames and Mac Daniels (1947), was mainly descriptive and the emphasis was on the 'root-shoot transition' of the vasculature. These studies lead to concepts like splitting, twisting, recombination etc. to describe the mechanism for the existence of radial and collateral positions of the vascular tissues in the root and hypocotyl-cotyledon-epicotyl complex respectively. On the other hand, some of the workers believed that the seedling vasculature is discontinuous consisting of a hypocotyl-radicular axis on one hand and the cotyledonary on the other (Chauveaud, 1911; Esau, 1953; Dangeard, 1913). A proper understanding of the embryonic development of the vascular interrelation between cotyledons, the hypocotyl and the root is essential for the interpretation of the shoot and root connection (transition region) and of the origin of the plant as a co-ordinate shoot-root system.

Marsdon and Bailey (1955), Bisalputra (1961) and Philip (1974) reported that the first formed vascular elements of the root, hypocotyl, epicotyl and cotyledons are discontinuous. The present investigations aim to study the exact method by which the vascular connection between the root and hypocotyl, the hypocotyl and cotyledons and the hypocotyl and plumule is established in cashew.

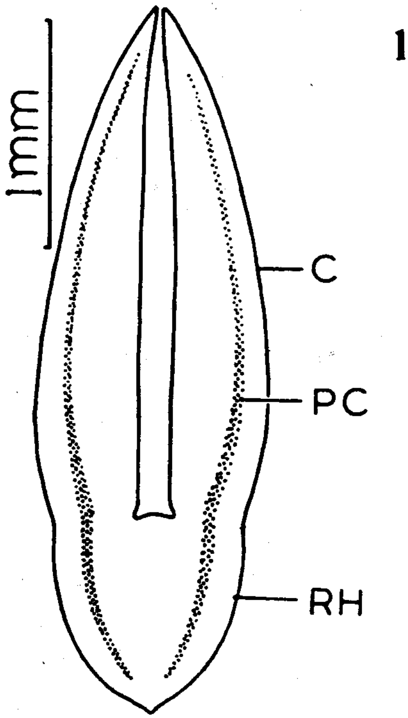
Materials and Methods

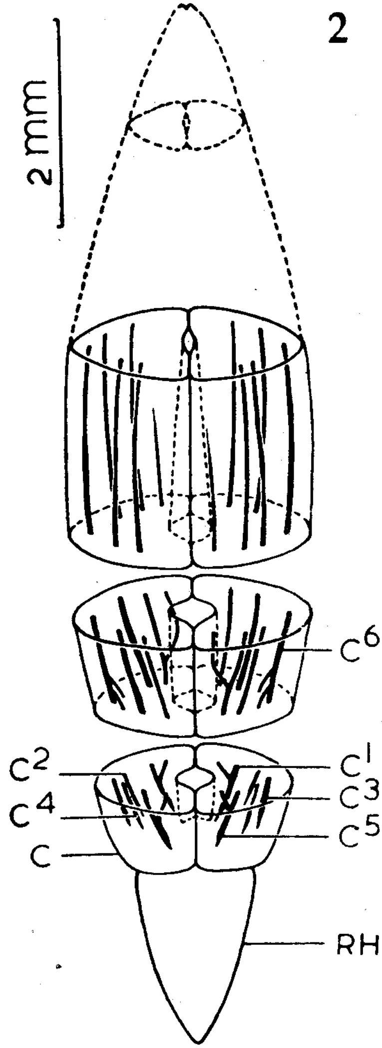
The mature nuts of cashew were collected from trees growing in Calicut University Campus. For the study of the primary vascularization in the young embryos, immature nuts were also collected. The embryos were fixed in F. A. A. immediately after collection and were dehydrated as per Johansen's (1940) tertiary-butyl alcohol series and embedded in Paraffin wax of melting point. 56 – 58°C. Serial sections of 10-13 micra thickness were stained in a combination of Heidenhain's iron-haematoxylin, tannic acid, ferric chloride and saffranin and mounted in DPX mountant.

Results

A 3 mm embryo basically consists of two cotyledons, each 2.25 mm in length and the radicle measuring 0.75 mm in length (Fig. 1, C,RH). The young embryo at this stage consists of a single layered protoderm, procambium, and the large more vacuolated lightly staining cells constituting the ground tissue. In longisection, the procambial cells, compared to the adjacent ground meristem are narrower and elongated in shape with denser cytoplasm and appear to be deeply stained. The continuity between the procambium in root, hypocotyl and cotyledons has already been established at this stage as is shown in Fig. 1(PC). The procambium forms a hollow cylinder in root-hypocotyl axis. The procambial strands supplying the cotyledons appear to differentiate in acropetal manner.

In 10 mm long embryos the first protoxylem elements differentiate at about 160 micra above the cotyledonary node in the cotyledons (Fig. 2). These protoxylem elements are characterised by their lignified secondary





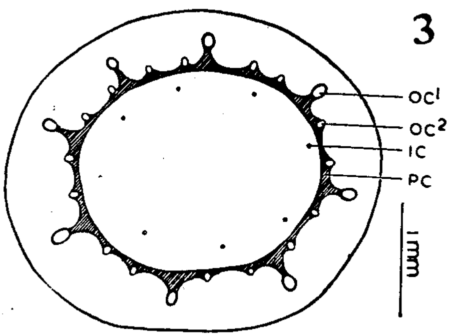


Fig. 1. L.S. young embryo showing procambial continuity.

Fig. 2. Three-dimensional representation of xylem strands in the cotyledons of young embryo in which stage the xylem is not differentiated in the root-hypocotyl axis.

Fig. 3. C.S. hypocotyl showing procambial ring and oil canals. (C, cotyledon; $C^1 - C^6$, cotyledonary xylem strands; IC, inner row of oil canals; OC^1, OC^2, outer rows of oil canals; PC, procambiaum; RH, root-hypocotyl axis).

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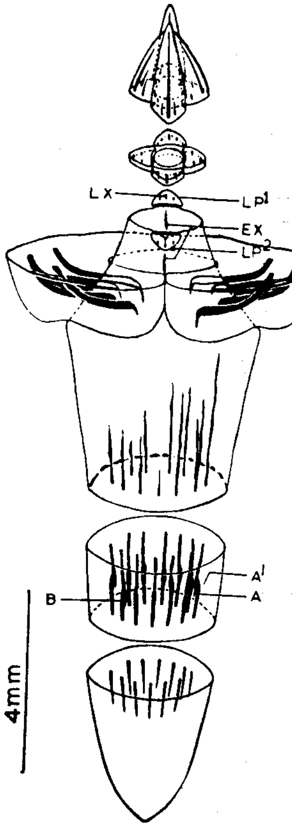

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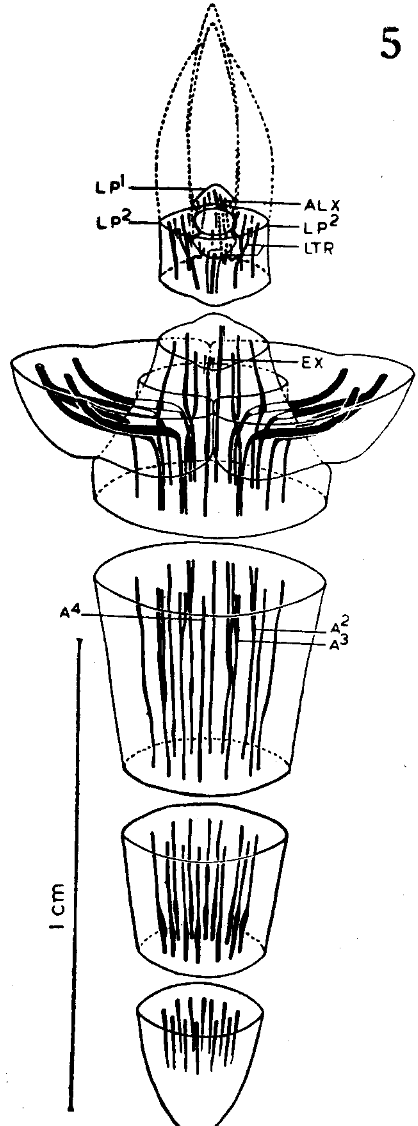

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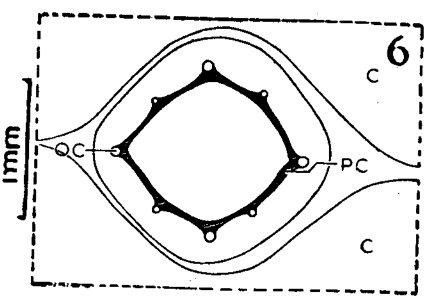

Fig. 4. Three-dimensional reconstruction showing discontinuous nature of xylem strands in the embryo.

Fig. 5. Three-dimensional diagram of a mature embryo showing continuity of xylem strands.
Fig. 6. C.S. epicotyl showing procambial ring and oil canals. (A, zone where root xylem and hypocotylary xylem separated by parenchyma cells; A^1, oldest part of the root where xylem initiation starts first; A^2, the point where the median xylem strand of the second pair of leaf join with the hypo-cotylary xylem strand; A^3, the point where lateral traces of the leaves join with the hypocotylary strand after its union with the epicotylary strand; A^4, the point where median strand of the first pair of leaf join with the hypocotylary strand; ALX, additional leaf xylem; B, root and hypocotylary xylem differentiated very closely; C, cotyledon; EX, epicotylary xylem; LP^1, first pair of leaf primordia: LP^2, second pair of leaf primordia; LTR, lateral traces; LX, leaf xylem; OC, oil canal; PC, procambial ring).

walls and the absence of living contents. Further wave of differentiation of protoxylem within the procambium can perfectly be correlated with the direction of differentiation of the procambium in the cotyledons. Of the five protoxylem strands (Fig.2, $C^1 - C^5$) thus differentiated in each cotyledon, the central three (Fig. 2, C^2, C^3, C^4) combine at 450 micra above the cotyledonary node to form the median trace supplying the cotyledons (Fig.2, C^6). At this stage the differentiation of protoxylem has not taken place in the hypocotyl or in the root (Fig.2, RH).

In the mature embryos at the time of seed shedding, the procambial cylinder in the root and hypocotyl is associated with two rows of oil canals (Fig. 3, OC^1, OC^2) outer to the procambial cylinder. Each oil canal of the first row is accompanied by one oil canal of the second row on either side. In the hypocotyl an additional row of canal got differentiated from the inner region of the procambium facing the pith region (Fig.3, IC). Thus differentiation of an additional row of oil canal serves as a clue for the delimitation of the hypocotyl from the root. Differentiation of the protoxylem and subsequent elements commence at about 3.8 mm (Fig.4, A^1) from the radicular end of the embryo, which is the oldest part, and then continues to differentiate acropetally. The transverse wave of differentiation of the xylem elements of the root is centripetal. In the cotyledon on the other hand, as far as it could be determined, the longitudinal course of differentiation of protoxylem do not appear to follow a clear cut direction. The transverse course of differentiation of xylem elements of this region is centrifugal.

In the mature embryo and young seedling serial sections show two pairs of leaf primordia (Fig.4, LP^1, LP^2), the first pair attached to the epicotyl in an opposite decussate manner to the cotyledons. Median longitudinal sections passing through the cotyledons and serial transections show three procambial bundles in each of the leaf primordia. The first protoxylem elements were found to differentiate in the middle procambial group at the base of the leaf primordia and subsequently in the two lateral procambial bundles, thus forming three seperate xylem bundles (Fig. 4, LX). The longitudinal differentiation of first formed xylem elements is both acropetal and basipetal. Additional xylem bundles are also seen differentiating in between the three (Fig.5, ALX). The second pair of leaf primordia (Fig.4, 5, LP^2) on the epicotyl is initiated at right angles to the first and the pattern of differentiation of the primary xylem in these leaf primordia also follows that of the first pair of leaves.

Below the point of departure of leaf traces, a ring of procambial tissue in the epicotyl (Fig.6, PC) was seen differentiated acropetally. The first xylem elements of the epicotyl also differentiate acropetally and basipetally and in line with the central trace of the first pair of leaves (the leaf that is tound at right angle to the cotyledons) (Fig.4, 5, EX). The median xylem frace from each leaf joins the xylem of epicotyl and become connected to it. The traces from the first pair of leaves further differentiate basipetally down the epicotyl and join the hypocotylary bundles at the tip. (Fig.5, A^4) and those from the second pair of leaves join the hypocotylary bundles side by side (Fig.5, A^2) at a level of about 8,500 micra above from the root tip. It is significant to note that the lateral traces (Fig. 5, LTR) of the two adjoining leaves combine and connections re-established with the hypocotylary strands on their sides (Fig.5, A^3).

Establishment of vascular connections : It has already been pointed out earlier that the proto-xylem in the root has differentiated earlier than that of the hypocotyl. In the connection region between the root and hypocotyl, the first protoxylem element of the hypocotyl though it appears to differentiate in close proximity with the projecting root xylem in a large number of cases (Fig.4, B) in general, it is often separated atleast by one parenchymatous cell (Fig.4, A). In such cases, later formed metaxylem cells differntiate in such positions so as to establish contact with the root xylem. At slightly higher level of the hypocotyl, collateral vascular strands become discernible and this is maintained throughout the hypocotyl.

In the cotyledons of *A.occidentale,* the primary xylem initiation takes place at the base and proceeds upwards i.e., acropetally, and this feature is evidenced by observations of embryos of different ontogenetic stages. The protoxylem elements that are differentiated in the hypocotyl come in proximity to the base of the cotyledonary strands. As reported in *Catharanthus roseus* (Philip, 1974) the metaxylem elements are differentiated between the parimary xylem strands of the cotyledons and tips of the hypocotylary strands there by establish connection between the vasculature of cotyledons and hypocotyl.

The eight groups of protoxylem elements that are differentiated at the epicotyl further differentiate acropetally and basipetally and join the hypocotylary xylem side by side (Fig.5).

Discussion

In *A.occidentale,* the procambium does not form a solid cylinder in root-hypocotyl axis. A similar situation has already been reported in *Juglans regia* (Nast, 1941), *Annona squamosa* (Hayat and Canright, 1965). Thus the occurrance of a hollow cylinder of procambium in root appears to be associated with tree habit as against the condition of solid cylinder of procambium reported in dicotyledonous herbaceous members like *Phlox drummondii*

(Miller and Wetmore, 1945), *Tridax procumbens* (Padmanabhan, 1968) and *C.roseus* (Philip, 1974).

Some of the concepts and terms used in text books on plant anatomy in relation to seedling vasculature need reconsideration as cells in plant part sections differ considerably from those during ontogeny of organs. Data available on the 'transition-region' deals with the vascular connection between the shoot and root at early stage in the development of the seedling without consideration to the developmental history. This has misled the anatomists to the conclusion that the seedling has a single unit of vascular system and by mechanisms such as splitting, twisting, rotation, recombination etc. the two systems, root and shoot, with xylem and phloem arranged in different geometric configurations are put into continuity (Van Tieghem, 1891; Eames and Mac Daniels, 1947).

On the other hand, the vasculature of the seedling was considered to be initially discontinuous consisting of two systems, a radicular hypocotylary part and a cotyledonary part by Dangeard (1913) and Thoday (1939). Deshpande and Singh (1967) observed two distinct vascular units - the root-hypocotyl-cotyledon unit and a shoot unit - in the seedlings of *Withania somnifera*. Bisalputra (1961) based on his studies on some members of Chenopodiaceae consider the seedling at its initial stage to have three separate vascular systems viz. those of epicotyl, the cotyledon, and the radicle and connected developmentally with one another. The present findings in *A. occidentale* does not fully agree with any of the above observations. Here separate vascular units are seen differentiated in root, hypocotyl, cotyledons and epicotyl and are initially of independent origin.

In *A.occidentale,* protoxylem is initiated first in the oldest part of the cotyledons and then in root and subsequent mode of differentiation is acropetal. The initial discontinous nature of the protoxylem strands in cotyledons, root, hypocotyl and epicotyl is very much evident in this study. The vascular elements which initiated independently in root, hypocotyl, cotyledons and epicotyl, at a later stage get connected by a simple process of 'bridging-up' and the vascular continuity is established.

Acknowledgement

The author is thankful to Dr. V.J. Philip, Reader, Department of Botany, University of Calicut for his valuable gudiance and to Dr. B. K. Nayar, Professor and Head of the Department of Botany for encouragement and providing facilities for successful completion of the present work. Thanks are also due to Dr. K. Unnikrishnan, Reader, Department of Botany, for going through the manuscript.

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Development, Differentiation and Evolution of Sex-Dimorphism in Cashew

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Abstract

The ontogenetic development of flower buds and distribution of matabolites in developing tissues in cashew revealed that dimorphic differentiation of stamens and pistils occurred quite at an early developmental stage of the bud in response to the differential distribution of protein. The control of such differentiation leading to dimorphic phenotypes of sex organs within the indeterminate infloresecnce is said to be primarily genetical. The probable origin and evolution of sex-dimorphism from the ancestral monomorphic condition has been discussed in relation to cross pollination.

Introduction

Cashew, *Anacardium occidentale* L., is a cross pollinated tropical tree crop. Studies on its flowers mostly refer to floral biology in respect of sex ratio and sexual phase sequences during anthesis (Aiyadurai and Koyamu, 1957; Rao and Hassan, 1957; Damodaran, Abraham and Alexander, 1965; Pavithran and Ravindranathan, 1974 and 1976). Information on development and differentiation of dimorphic phenotypes of sex organs in cashew is scanty. Considering the significance of sex-dimorphism as a cross pollination device the present work was carried out as a preliminary step towards understanding certain aspects of development and differentiation of pistil and stamen in relation to the evolution of dimorphic expression of the sex organs in cashew.

Materials and Methods

Flower buds of different ages were fixed in Cornoy's fluid, subsequently dehydrated, paraffin-waxed and sectioned in 10μ thickness. The sections were later stained with 0.1 per cent acquous solution of mercuric bromophenol blue for protein (Mazia, Brewer and Alfert, 1953). The buds were arbitrarily classified into sepal-clad, sepalo-petal-clad and preanthetic for convenience. Observation was made on protein distribution in different developing floral organs of buds.

Results and Discussion

Cashew has polygamomonoecious inflorescence of indeterminate growth prevailing over several months. This habit poses difficulty in locating the exact age of flower buds. Flowers occur in clusters at the terminal rechilla of the panicle and are small, whitish green at anthesis and turn red later with penetrating aroma. The inflorescence produces nil to low percent of hermaphrodite flowers and numerous staminate flowers (Rao and Hassan, 1957; Damodaran, Abraham and Alexander, 1965; Northwood, 1966; Ascenco and Mota, 1972, Pavithran and Ravindranathan, 1974). Alves (1971) and Mota (1973) recorded occurrence of female and neuter flowers and also various types of flower abnormalities in cashew. The development of gynoecium is deterministic of sex-dimorphism of flowers into staminate and hermaphrodite. Histochemical studies on flower buds of different age revealed that the initial pistillar tissue in the expectant hermaphrodite flower bud had more protein accumulation and simulated growth, while in the expectant male bud the pistil zone showed less or poor protein accumulation and least development as indicated by its abortive growth and weak staining (Figs. 1-5). No appreciable differential protein accumulation has been observed in the case of stamens, though the single fertile stamen showed better growth rate at an early sepal-clad stage of the bud (Figs. 1 & 2).

It appears from these observations that probably protein has an important role in gynogenic induction, differentiation and development. The preponderance of staminate flowers could be due to competition for metabolities during ontogenetic development of buds in the indeterminate inflorescence. Pistil, being the late differentiated organ in the bud primordia, it is likely that metabolic insufficiency could be the cause for the low production of hermaphrodite flowers.

Ascenco and Mota (1972) proposed that male flowers might have derived from the ancestral hermaphrodite flowers by gradual loss of function of the gynoecium. However, the present study showed that the situation in cashew with regard to the formation of pistillode might be an instance of dystrophic morphogenesis.

It seems justified to hypothesize that dimorphic sex organs in cashew might have evolved from an ancestral condition of monomorphic bisexual flowers (which might have been predominantly self pollinated prior to its attainment of high adaptability) to a condition of hermaphroditism with dimorphic stamens. The dystrophic morphogenesis of the pistil might have evolved later or parallely leading to high degree of cross pollination.

It is concluded that subtle information on the morphogenetic control of initiation, development and differentiation of sex organs especially that

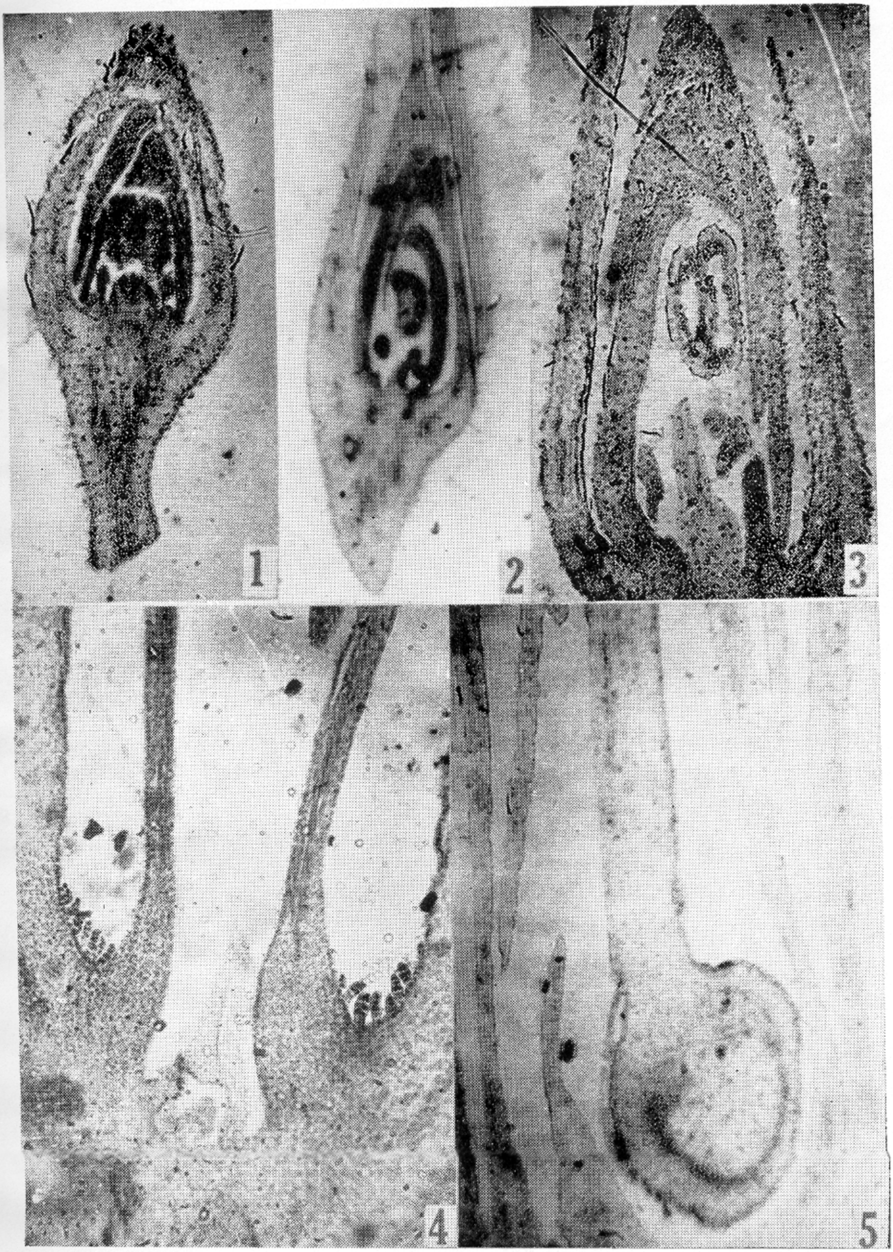

Fig. 1. Deeply stained and developing pistillar tissue of a hermaphrodite flower bud at an early stage. 2. Staminate flower bud showing poorly developed and weakly stained pistillar tissue at an early state. 3. Poorly stained aborted pistillar structure in a sepal clad late bud. 4. Typically least stained pistillode of a male preanthetic bud. 5. Fully stained and developed fertile pistil of a hermaphrodite flower bud at the preanthetic stage.

of pistil, is a prerequisite for experimental manipulation of sex ratio in cashew in order to increase the yield potential.

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A Study of Variation in Flowering Characters of Cashew Germplasm

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Abstract

The observations were made on 100 accessions of cashew germplasm on flowering behaviour, fruit set, sex ratio and fruit drop. Apart from three flowering phases viz. male phase, mixed phase and second male phase about 50 per cent of the accessions showed bisexual phase initially. The duration of flowering in a panicle varied from 42-123 days while in about one thrid of accessions it varied between 61 – 70 days. The bisexual flowers in a panicle ranged from 0 – 42 per cent while in 46 per cent of accessions it ranged between 1 – 5 per cent. Among the observations made less variation was noticed in duration of flowering, duration of mixed phase and percentage of male flowers in mixed phase. Maximum variability was observed in mean fruit set and percentage of flowers in first male phase.

Introduction

The inflorescence in Cashew is a polygamomonoecious possessing both hermaphrodite and male flowers in the same panicle. During the last two decades, research workers on cashew have studied the structure of the flower, floral biology, sex ratio, fruit set and vegetative propagation in the crop (Copeland, 1971; Northwood, 1966; Damodaran, Abraham and Alexander, 1957; Rao and Hassan, 1957). No attempts have been made so far to study the variability that exists for their flowering behaviour, sex ratio and fruitset from a large population having a wide genetic base. In this paper results of observation recorded on 100 accessions of cashew for the variation in flowering behaviour, fruitset and sex ratio are presented.

Materials and Methods

The study was undertaken at Central Plantation Crops Research Institute, Regional Station, Vittal. The plants observed for the study were from the germplasm collection of the institute which included the promising exotic and indegenous selections and hybrids collected from Vengurla, Vridhachalam, Bapatla and Anakkayam cashew research centres in India. The

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lata were recorded from 1974 to 1977. A total of 100 trees have been obser-
ed of which 24 were during 1974-75, *43 during 1975-76 and 33 during*
976-77. Five unopened panicles per tree per accession were selected and the observations were recorded once in three days on number of flowers opened, number of male flowers, number of bisexual flowers, number of fruits set number of fruits harvested, etc. between 8.00 a.m. to 12 noon. The flowers were marked by cutting one or two petals with a small scissors. The panicles were protected against tea mosquito (*Helopeltis antonii*) attack with endosulfan (0.05%) spray.

Results and Discussion

The duration of flowering in a panicle varied from 42 to 123 days with a mean of 71.8 days (Table 1). A maximum of 33 per cent of accessions flowered between 61-70 days. The duration of first male phase varied from 0 to 40.2 with a mean of 5.1 days but 30 per cent of the accessions fell in the range of 0.1 to 1 day. The duration of bisexual phase varied from 0 to 13.2 days (mean 1.2) and 30 per cent accessions fell in the range of 0.1 to 1.5 days. The duration of mixed phase varied from 17.4 to 103.4 days with a mean of 50.2 but in 30 per cent accessions the duration was 41-50 days. The second male phase varied from 1.8 to 41.4 days. The contribution of male flowers from the first male phase to the total male flower production varied from 0 to 68.2 per cent with a mean of 6.3 and 31 per cent accessions contributed below 1 per cent. The male flowers percentage in the mixed phase varied from 26.0 to 90.3 per cent giving a mean of 71.6 per cent but 43 per cent accessions fell in the range 71-80 per cent. The male flowers in second male phase varied from 0 to 38.9 per cent (mean 9.9) and 41 per cent accessions had 1-5 per cent flowers. Percentage of bisexual flower over total flower production varied from 0 to 41.6 per cent, with a mean of 10.7 per cent but 46 per cent accessions had only 1-5 per cent bisexual flowers. Mean bisexual flowers per panicle between accessions varied from 6.4-166.4 and 25 per cent accessions had only 1-20 flowers. The mean fruit set per panicle varied from 0 to 18.2 with a mean of 4.4. and 46 per cent accessions had below 1.5 nuts. The percentage of set over bisexual flower production varied from 0-29 per cent (mean 4.4) but 27 per cent accessions falling in the range upto 2 per cent. Sex ratio, the proportion of bisexual flower to male flowers, varied from 1:1.4 to 1:218.8 (mean 1:19.4) and 43 per cent accessions had sex ratio 1:2.0 - 1:8.0. Mean number of male flowers per panicle varied from 117.8 to 1583.6 with a mean of 445.4 and 26 per cent accessions had 400–500 flowers per panicle.

Minimum variation was noticed in duration of flowering, duration of mixed phase and percentage of male flowers in mixed phase. Maximum variability was observed in mean fruit set and percentage of flowers in first male phase. All other characters showed high degree of variability within and between accessions. In addition to the three flowering phases described by Pavithran and Ravindran (1974) one more phase i.e. bisexual phase was noticed during the present study, where the panicle starts anthesis with bisexual flowers. In 54 per cent of accessions this bisexual phase preceded the mixed phase instead of first male phase. There were some accessions which directly entered into the mixed phase, where male and bisexual flowers appeared together.

TABLE 1. **Variation in Flowering Behaviour of Cashew Germplasm.**

Sl. No.	*Descriptors*	*Mean*	*Standard deviation*	*Coefficient of variation*
1.	Duration of flowering	71.8	12.3	17.1
2.	Duration of I male phase	5.1	3.3	163.2
3.	Duration of bisexual phase	1.2	1.8	158.3
4.	Duration of mixed phase	50.2	14.1	28.7
5.	Duration of II male phase	15.3	3.2	53.5
6.	% flowers in I male phase*	6.3	13.2	209.9
7.	% male flowers in mixed phase	71.6	14.7	20.5
8.	% male flowers in II male phase	9.9	10.5	105.9
9.	% bisexual flowers over total	10.7	8.1	76.2
10.	Sex ratio	1:19.4	1:29.1	1:150.2
11.	Mean fruit set	4.4	9.6	216.2
12.	% set over total bisexual flowers	4.4	5.0	112.8
13.	Mean male flower per panicle	445.4	198.9	44.6
14.	Mean bisexual flowers per panicle	53.4	37.4	70.1

* The percentage contribution of first male phase to total flower production.

Damodaran, Abraham and Alexander (1965) reported that the proporation of perfect flowers varied from as low as 0.45 per cent to 24.9 per cent in different trees and low positive correlation between sex ratio and yield. In the present study the percentage of bisexual flowers varied from

0 to 41.6%. Madhava Rao and Hassan (1957) and Damodaran, Abraham and Alexander (1965) have reported that 4–6 per cent bisexual flowers attained maturity. Our observation reveals that the percentage of set varied from 0-29 with a mean of 4.4. Therefore the poor fruit set in cashew may not be due to the non-availability of bisexual flowers and may be due to non-availability of pollen as suggested earlier (Nayar, Vimala and Kumaran, 1979).

The two important problems in cashew are poor fruit set and protracted harvesting period. The present study indicates the possibilities of identifying the plant typ s with synchronised flowering habit and a shortest mixed phase which will reduce the duration of harvesting period from three months to one month.

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Discussion

K.K. Vidyadharan: You got more than 50 per cent set when artificially pollinated. What are the limiting factors for the poor set in cashew under natural conditions? Is it due to want of sufficient pollen in the atmosphere? or for want of pollinating agents?

P. M. Kumaran: According to our observations the reason for poor fruit set is due to lack of pollination. Since cashew pollen is sticky the availability of pollen in atmosphere is also limited.

R. C. Mandal: In cashew fruit set is extremely low, eventhough 50 per cent bisexual flowers are produced. What are the possible lines of work to be undertaken to increase the fruit set, aiming at realising its production potential.

P. M. Kumaran: The two problems in cashew are poor set and immature fruit drop. Even if the percentage set is more in some accessions the yield is considerably low due to fruit drop. So reasons for fruit drop are to be analysed.

J. G. Ohler: The pollination deficiency was found to be a limiting factor in fruit set. It would be interesting to continue observations till after yield to verify if reduced fruit set also leads to reduced yield. Ecological factors such as water or nutrient deficiencies may cause premature fruit drop that could neutralise the effect of increased fruit set.

Effect of Gibberellic Acid on Variations in Free Amino Acid and Total Protein Contents in Developing Kernal of Cashew

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Abstract

Free amino acids and total protein contents have been studied in three different developmental stages of kernel in *Anacardium occidentale* L., after foliar treatment with 40 ppm and 50 ppm gibberellic acid. The effect of GA_8 on free amino acid and protein contents vary according to the concentrations of the hormone used, but does not follow a uniform pattern. Tryptophane, leucine (s), aminobutyric acid, valine-methionine, glutamic acid, alanine, aspartic acid, glycine and cystine occur in assayable amounts in the early kernel. There is a marked reduction in the total amount of free amino acid as the fruit matures, and this decline is steeper in the treated category. GA_8 treatment leads to qualitative and quantitative changes in the free amino acid: cystine, which is absent in the control kernels, occurs in significant concentration in the treated samples; and hydroxyproline though present only in traces in control, can no longer be detected in treated ones. The probable significance of the changing amino acid picture during kernel development in the treated and untreated plants is discussed.

Introduction

Gibberellins are known to replace and/or boost certain of the environmental factors for flowering in large number of plants belonging to different categories (Krishnamoorthy, 1975). Numerous species of plants treated with exogenous GAs respond with increase in fruit set and decrease in fruit drop resulting in higher yields (Moore and Ecklund, 1975; Valdovinos, 1975). Murthy, Kumaran and Nayar (1975) on the other hand found that GA has little effect on cashew. There have been correlative studies of the levels of GA and seed development in different plants (Skene and Carr, 1961; Ogawa, 1963; Hashimoto and Rappaport, 1966) but there is just scanty information on the GA induced change of free amino acid and total proteins during the development of cashew kernel.

Materials and Methods

Two healthy cashew trees growing in the Calicut University Campus were selected for the present study. From each tree some branches were set apart as control and others were treated with 40 and 50 ppm GA_3, a method of growth regulator application and control studies that would bear similarity with the works of Murthy, Kumaran and Nayar (1975), Dhuria, Phutani and Parmar (1976) and Zur and Goren (1977). The control branches were treated with distilled water, with a hand sprayer, the spraying done at 6 p.m. on five alternate days, prior to the flower initiation. Fruits of the early stages (K_1) were collected after three weeks from anthesis, the K_2 stage after six weeks and finally grey nuts after eight weeks as the K_3 stage. Another set of samples for each stage was collected for total protein studies. They were fixed in TBA paraffin series and finally embeded in paraffin (S.M.P. 58°C). Sections were cut at 9–12μ thickness (Johansen, 1940). Following the method of Mazia, Brewer and Alfert (1953) the staining for total protein was done with mercuric bromophenol blue. Control slides were run as per the method detailed by Jenson (1961).

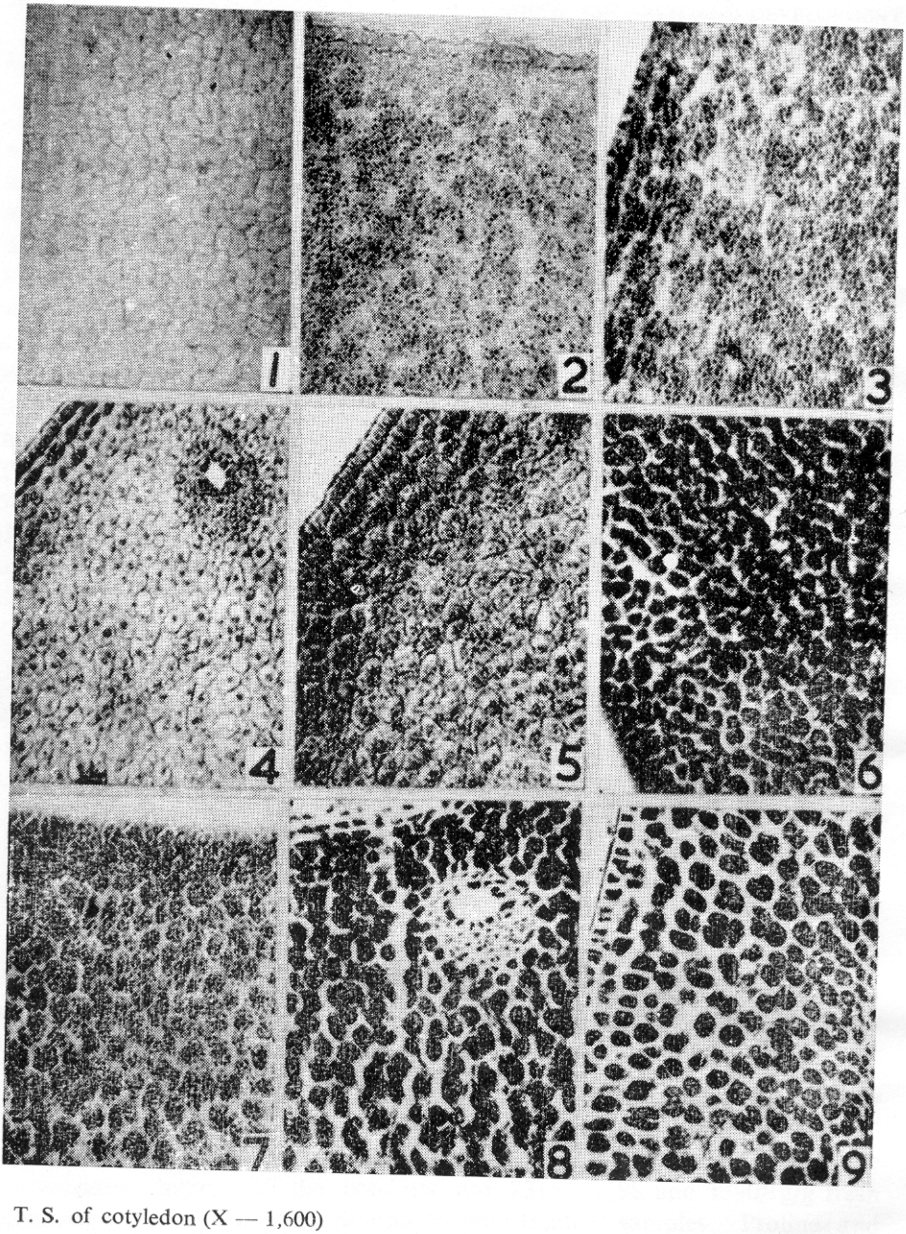
For the amino acid study, each lot of freshly decoated cashew kernel (5 g) was crushed in 80 per cent ethyl alcohol, centrifuged, and supernatant dried at 60°C. Samples were prepared in 1 ml of 1:1 phenol-butanol and spotted on Whatman's filter paper No. 1. The free amino acids were analysed and estimated following the methods detailed by Porter, Margolis and Stamp (1954), Stepka (1957) and Block, Durram and Zwiige (1963). Quantitative estimation was carried out with Spectronic-20 colorimeter.

Results and Discussion

The kernel during the K_1 phase showed marked alternation in the qualitative and quantitative pattern of free amino acids (Table 1). Cystine, which is absent in the control kernels, occurs in significant concentration in the treated samples.

Hydroxyproline, though present only in traces in control was totally absent in the treated. There is an appreciable drop in the total amino acid content by weight, the drop being of higher magnitude when the hormone concentration increased; the contents are 2315, 1798 and 1390μg/g fresh tissue respectively in control, 40 and 50 ppm treated samples. Proline and tyrosine present in significant amount in the control, are reduced to trace quantities in the treated samples, valine-methionine undergo a marked decrease on treatment with 40 ppm hormone and are reduced to trace concentrations when 50 ppm hormone is applied.

γ–Aminobutyric acid is reduced to low level in the treatment with 40 ppm, but the drop is some what less when 50 ppm is used. Glycine, present in



T. S. of cotyledon (X — 1,600)

Fig. 1, 2, 3 – Untreated early, mid and late phases

Fig. 4, 5, 6 – 40 ppm GA_3 in early, mid and late phase

Fig. 7, 8, 9 – 50 ppm GA_3 in early, mid and late phase

Note the increasing presence of protein granules in the treated ones as the development proceeds.

the traces only in the control, occur in the higher concentrations in the treated samples. The position of tryptophane as the most abundant amino acid in control is taken by glutamic acid in the treated. Aspartic acid also registered a marked increase in the treated samples, occupying the second position.

In the early phase in both 40 and 50 ppm GA treated cases, the cotyledonary cells have higher total protein contents than those of the control (Figs. 1, 4,7). In the 40 ppm treatment, a few Hg-bromophenol blue stained granules can be made out (Fig. 4); whereas none in the case of control (Fig. 1). There is greater accumulation of such granules in the epidermal cells and in the cells surrounding the oil canals (Fig. 4). Under the treatment with 50 ppm, the cells are loaded with bigger granules stained for proteins (Fig. 7).

The qualitative distribution of free amino acids in treated mid phase is the same as that in the early phase (Table 1). There is a drop in the total free amino acids on treatment with 40 ppm hormone when compared to that of the control mid phase (from 593μg of control to 417μg). However, in the samples treated with 50 ppm there is no change in the total amino acid content (592μg/g). The most abundant amino acid by weight at either contentration of GA_3 is glutamic acid, followed by tryptophane in 40 ppm treatment and by aspartic acid in 50 ppm treatment. Proline is present only in traces. Cystine is present, representing a qualitative difference from the control. A difference between the two concentrations shows up in valine-methionine when 40 ppm is applied, but there is over 3-fold increase when the hormone is at 50 ppm.

GA treatment has brought about more intense total protein stainability in the cotyledonary cells in the mid phase compared to the control (Figs. 2, 5, 8). There is greater scattering of the granules under the treatment with 50 ppm. (Fig.8).

There is negligible drop in total amino acids, as the fruit matures, on treatment with 40 ppm (205 to 195μg) and an appreciable rise in 50 ppm treatment (205 to 242μg) when compared to that of the control. Hydroxyproline continues to be absent in both the treated samples. With 40 ppm hormone, glycine is reduced to the trace level prevailing in the control. With 50 ppm, significant amount of glycine is present. Proline continues to be in traces. Both glutamic acid and aspartic acid are present in appreciable amount in the treated samples. Tyrosine is present in traces as in the control, 40 and 50 ppm GA treated contyledonary cells are more deeply stained for protein than the control (Figs. 3,6,9). There is higher concentration of protein granules in treated ones in the final phase.

TABLE 1. **Effect of GA_3 on the Amino Acids in the Kernel Development of Cashew (μg/g fresh weight)**

Amino acids	*CONTROL*			*40 PPM*			*50 PPM*		
	K_1	K_2	K_3	K_1	K_2	K_3	K_1	K_2	K_3
Try	700	278	22	144.1	81.4	24.2	113.3	64.0	25.0
Leu (s)	540	194	7	27.7	20.0	2.8	34.0	20.0	7.1
GABA	400	11	18	33.3	15.0	4.2	46.3	28.4	9.1
Pro	195	65	t	t	t	t	t	t	t
Val/Met	145	20	134	55.5	t	15.0	t	72.0	23.2
Tyr	135	t	t	t	t	t	t	t	t
Glu	100	15	t	644.0	95.7	108.5	580.0	112.0	121.0
Ala	55	6	21	222.0	42.8	12.0	146.0	24.0	12.3
Ser	25	t	3	105.5	17.0	t	33.3	56.0	12.5
Asp	20	4	t	233.0	57.1	14.0	153.3	88.0	14.3
Arg	t	t	t	t	t	t	t	t	t
Asn	t	t	t	t	t	t	t	t	t
Gly	t	t	t	222.0	60.0	t	146.6	68.0	17.8
OH-Pro	t	t	t	ND	ND	ND	ND	ND	ND
Lys	t	t	t	t	t	t	t	t	t
Orn	t	t	t	t	t	t	t	t	t
Phe	t	t	t	t	t	t	t	t	t
Thr	t	t	t	t	t	t	t	t	t
Cys	ND	ND	ND	111.0	20.5	14.0	133.0	60.0	t

K_1 – 3 weeks old; K_2 – 6 weeks old; K_3 – mature kernels; t – trace; ND – not detectable

In GA treated cashew kernels the amino acid contents show a progressive decrease with the growth and maturation of the nut, and greater accumulation of protein. The response to hormone treatment is qualitative as well as quantitative. Cystine, which is absent in the control samples at all stages is abundant in the treated samples, and it appears that the transformation of inorganic sulphate to cysteine the precursor of cystine, is blocked in the control and depressed as a result of GA_3 action. Another qualitative chage is disappearance of hydroxyproline. Since hydroxylation of proline occurs subsequent to incorporation into polypeptide chain and the fact that the hydroxyproline is absent in treated samples, it is possible that the endogenous degradation of protein is virtually abolished in the hormone treated samples. Glutamic acid is present as the most abundant amino acid by weight in all stages of treated samples, which is in keeping with its central role in metabolism. Glutamate is formed by reductive amination of $\propto$-ketoglutarate. The increased presence of aspartic acid in the treated samples compared to the control signifies utilization in the formation of nucleotides and hence of nucleic acids. Aspartate can be formed also by the reductive amination of oxaloacetate, or by the amination of fumarate.

The biosynthesis of several amino acids inclusive of glutamate and asparate is dependent on the functional activity of mitochondria. It is known that as seeds mature mitochondria decline in their metabolic activity (Breidenbach, Castelfranco and Criddle, 1967; Kolloffel, 1970; Nawia and Asashi, 1971; Wilson and Bonner, 1971). Glycolitic intermediates and intermediates of the pentose phosphate pathway also participate in amino acid synthesis. Enzymes of these two pathways are known to occur in developing and maturing seeds in general (Duffus, 1970; Tasi, Salamini and Nelson, 1970; Baxter and Duffus, 1973; Turner and Turner, 1975). The altered amino acid distribution in the hormone treated plants, discussed above, suggests that GA_3 influence glycolytic and pentose phosphate pathway reactions and Kreb's cycle activity and thus in the anaerobic reaction mechanism.

The biochemical aspects of GA response have been reviewed by Jones (1973), Leopold and Kriedemann (1975). The promotion of growth by GA, whether by cell proliferation or elongation necessitates increased protein synthesis of DNA and forms of RNA and possibly also phospholipids. Treatment with GA results in a marked increase in the protein content of kernel at all stages of development. The onset of marked storage protein synthesis commences in the early phase iteself under the influence of GA_3 treatment in contrast to the control in which stained granules cannot be detected at this stage. GA treatment results in a pronounced enhancement of storage protein synthesis in the mature cashew kernel, insipte of the fact that total free amino acids remain more or less stationary or show better presence than the control.

Acknowledgement

We are indebted to Dr. P. S. Krishnan, Emeritus Professor of Biochemistry, University of Calicut for helpful discussions. Financial assistance from the University of Calicut and the Council of Scientific and Industrial Research to one of us (M.H.) is also gratefully acknowledged.

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Discussion

A.L.S. Tirimanna: In addition to normal metabolic role of glutamic acid it is possible that glutamic acid and its derivatives may play an important role in flavour enhancement in cashew kernels.

P.N. Ravindran: Cystine was absent in control but present in GA treated plants. Do you think that GA is acting as an inducer for the synthesis of sulphur containing amino acids, or what can be the method by which concentration of cystine has increased?

Molly Hariharan: I am not sure whether GA is an inducer for cystine-but as the concentration increases (from 40 to 50 ppm) the amount of cystine also increased from 111 to 133μg/g.

T. B. Dasaradhi: What is the effect of GA on the fruit set and kernel formation?

Molly Hariharan: There are reports that GA can induce more male flower formation. Studies show that GA reduces fruit set and increased weight and size of nut and apples.

Studies on the Effect of Plant Growth Regulators on Cashew

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Abstract

The extracts of cashew seeds when chromatographically assayed, showed to contain natural auxin IAA with an Rf of 0.30 and is very much similar to synthetic IAA. One more spot on the same chromatogram was found with biological activity in the slit hypocotyl of black gram. This compound was unidentified. The effect of plant growth regulators viz. GA, IBA, NAA and ClPA at 100 to 500 ppm for seed treatment, 25 to 100 ppm spray treatment and 0.1 – 0.4 per cent in lanolin paste on the seeds and seedlings was studied. Invariably all the growth regulators except ClPA stimulated high percentage of seed germination. ClPA at all concentrations inhibited the germination and root development. GA induced stem elongation in seedlings was due to increase in the cell number and cell elongation as observed in the cortex and pith regions of the stem sections of the second internode. The fresh and dry weights of shoots and roots showed increase with GA treatment.

Introduction

Seedlings with good tap root and number of lateral roots normally withstand transplantation shock and/or drought. Young seedlings of cashew usually do not produce lengthy tap root and secondary roots and probably for want of adequate root system, seedlings suffer heavy casualities especially during summer. Possibility of inducing better root and shoot development by treating either the cashew seed or seedlings with plant growth regulators with a view to reducing the mortality was investigated.

Materials and Methods

Seed treatment: Fifty cashew seeds of uniform weight, size and age were soaked for 48 hr in the growth regulators at 100, 200, 300, 400 and 500 ppm of Giberellic acid (GA_3), Indoleacetic acid (IAA), Indolebutyric acid (IBA), Naphthalene Acetic Acid (NAA) and Chlorophenoxy Acetic Acid (ClPA). Under each concentration five plants of the same age were examined on the 60th day after germination to study the effect of growth regulators on shoot and root growth.

Seedling treatment: After recording the initial shoot and root length, one month old seedlings of uniform vigour, shoot and root growth were treated with growth regulators as detailed below.

(a) *Spray treatment:* The aqueous preparation of growth regulators of GA, IAA, IBA, NAA and ClPA at 25, 50, 75 and 100 ppm were sprayed at weekly intervals.

(b) *Lanolin paste treatment:* The growth regulators in lanolin paste at 0.1, 0.2, 0.3 and 0.4 per cent were applied to five plants in each treatment at the growing tips of the seedlings. Suitable controls were provided in each case.

Weekly observations were recorded on growth rates of shoots and roots and the final shoot and root lengths were recorded after completion of eight weeks after treatment. Stem sections of the second internode of the GA treated seedlings were examined for anatomical changes. The dry weights of root and shoots of five plants were recorded.

Chromatographic assay: To examine the naturally occurring auxins in the seeds of cashew, 200 g of mature and viable seeds of uniform age were selected, the seed coats removed and the endosperm with the cotyledons were used for the assay. The material was extracted and assayed chromatographically adopting the procedure of Wright (1956). To estimate the biological activity of the auxins, the slit hypocotyl sections of black gram were employed (Shanmugavelu, 1967).

Results and Discussion

In all the treatments except in ClPA higher percentage of germination was recorded with 100 per cent germination in GA treatment. GA induced the highest shoot length at 500 ppm, the increase being 77 per cent over the control, whereas ClPA inhibited the shoot growth. However, GA failed to induce root growth which was less than the control. In NAA 100 ppm treatment the highest root length was recorded which was 92 per cent over the control. In ClPA treatment root inhibition was also noticed. In respect of production of secondary roots, NAA was found superior at 500 ppm. GA did not influence the production of secondary roots (Table 1).

When the extract of the cashew seeds was assayed chromatographically, it was found that the auxin IAA was detected besides an unidentified compound located at Rf 0.34 with activity in the bio-assay of slit hypocotyl of black gram.

Seedling Treatment: In spray treatment of IAA 50 ppm an increase in shoot growth of 69 per cent over the control was recorded. GA at 0.4 per cent

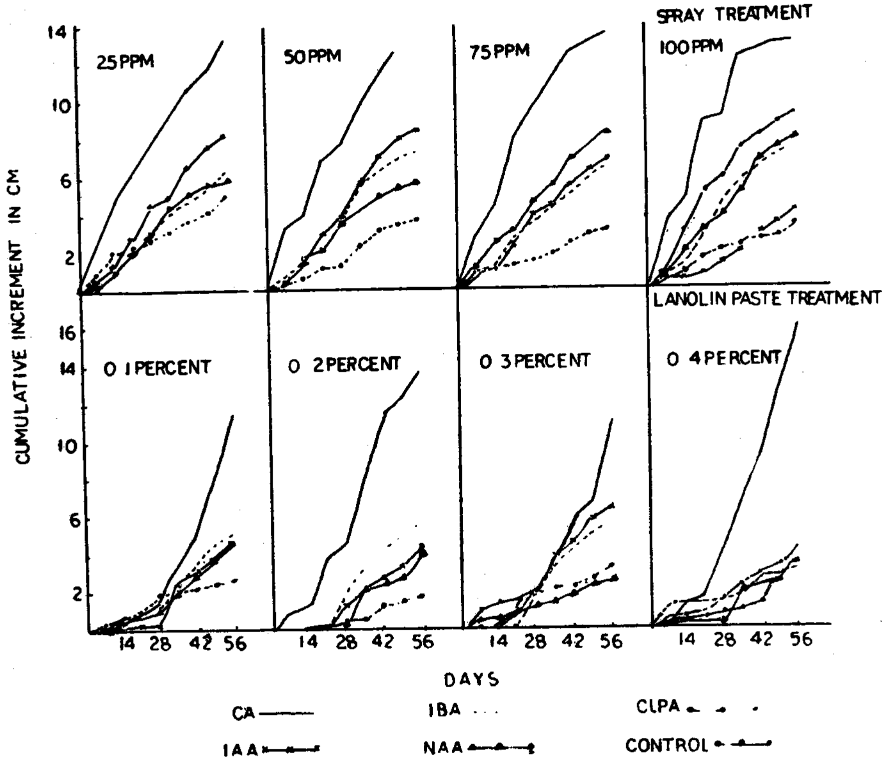
TABLE 1. **Effect of Plant Growth Regulators on Shoot and Root Development of Cashew by Seed Treatment**

Concentration in	*Length of shoot (cm)*						*Length of primary root (cm)*						*No. of secondary roots*					
ppm	*GA*	*IAA*	*IBA*	*NAA*	*ClPA*	*CD**	*GA*	*IAA*	*IBA*	*NAA*	*ClPA*	*CD**	*GA*	*IAA*	*IBA*	*NAA*	*ClPA*	*CD**
100	16.2	15.2	16.4	16.9	14.3	4.9	15.4	29.3	24.1	35.2	17.1	4.9	8.2	12.2	14.4	17.8	11.6	3.4
200	18.2	19.3	17.4	20.1	13.4	4.6	17.3	25.1	25.5	23.1	16.7	2.5	4.5	11.3	13.3	16.6	14.5	5.2
300	20.2	19.0	16.7	17.2	11.8	3.2	18.3	22.9	22.8	23.7	12.1	5.2	6.3	12.7	17.8	12.5	10.7	5.2
400	22.5	16.3	17.5	14.5	15.8	2.6	17.2	25.1	19.2	20.4	12.0	3.3	5.4	17.0	15.7	18.8	11.0	5.6
500	25.7	18.4	17.0	18.7	12.6	2.7	19.0	29.6	28.4	32.4	10.8	2.2	4.6	13.5	14.5	20.1	13.9	3.8
Control				14.5						18.3						4.9		

* $P = 0.01$

in lanolin paste also enhanced the shoot growth (94 per cent increase, over the control). Similar to seed treatment, ClPA caused inhibition of shoot showed epinastic effects. (Fig. 1).

Fig 1 EFFECT OF PLANT GROWTH REGULATORS ON THE GROWTH RATE OF SHOOT OF ANACARDIUM OCCIDENTALE



In the case of root growth (Table 2), IBA at 100 ppm induced the maximum root length of 36 cm as against 20 cm in the control. In the paste treatment, the highest primary root length was recorded in 0.2 per cent IBA treatment. Both GA and ClPA inhibited the primary root development. There was no variation in the production of secondary roots.

The fresh as well as dry weights of shoots and roots were increased by the treatment GA in the lanolin paste. The increase in the fresh and dry weights of the shoots had negative effect on the fresh and dry weight of roots. Elongated shoots in GA treatment showed both cell elongation and increase in the cell number. However, they are not commensurate with increase in the internodal length.

The effect of growth regulators on seed germination revealed that GA induced better seed germination of cashew than the other chemicals. The better seed germination induced by GA has been reported by number of workers (Khan, Gross and Smith, 1957; Barton and Chandler, 1957; Pfnur 1957; Fogle and McCrory, 1960). Accroding to Brian (1959), the plant tissues which respond to gibberelline alone are assumed to be self sufficient in auxin. Cashew seeds contained natural IAA. Shanmugavelu and Rangaswamy (1970) have suggested that the seeds of tree species contained natural occurrence of auxin which might probably regulate the seed germination. ClPA caused inhibition of germination which might be due to high concentrations or the chemical interference with the inherent auxin-kinin or auxin-gibberellin balance in the seeds.

Sumiki, (1952), Brain et al.(1955), have reported inhibition of root growth by GA. IBA at 100 ppm and at 0.2 per cent was found to induce maximum root growth. It was reported by Rao, Rao and Vazir Hassan (1957) that no lateral roots could be seen in the case of one or two month old seedlings, but in the present study by treating the seeds or seedlings with growth regulators the lateral root production was induced.

The most striking response of GA on cashew is the stem elongation. The number and length of cells in the cortex and pith regions were influenced by GA treatment. Therefore it appears that the stem elongation is predominantly due to cell elongation supplemented with cell division in the cortex and pith region, which support the views of Stowe and Tamaki (1957).

In cashew, increase in the fresh as well as dry weight of shoots and roots can be attributed to the increase in the overall assimilation and redistribution of materials within the plant.

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TABLE 2. **Effect of Plant Growth R**

Method	Particulars / Concentration ppm	GA				IAA		
		25	50	75	100	25	50	75
Spray	Initial shoot length (cm)	8.91	8.96	8.99	9.26	9.18	9.25	9.8
	Final shoot length (cm)	22.27	21.56	21.90	22.23	20.42	24.37	21.7
	C.D.	3.28	2.00	3.24	3.25	3.28	2.00	3.[illegible]
	Initial primary root length (cm)	9.62	9.30	9.13	9.66	9.00	9.33	9.[illegible]
	Final primary root length (cm)	13.31	13.56	13.25	17.86	25.83	33.13	28.34
	C.D.	3.68	4.00	3.72	3.44	3.68	4.00	3.72
	Number of lateral roots	8.80	10.80	11.60	10.50	18.00	17.60	14.00
	C.D.	2.92	2.13	3.46	3.46	2.92	2.13	3.46
Lanolin Paste	Concentration (%)	0.10	0.20	0.30	0.40	0.10	0.20	0
	Initial shoot length (cm)	8.86	7.71	8.34	8.72	8.35	8.10	8
	Final shoot length (cm)	21.43	23.51	19.52	25.97	13.06	13.58	13
	C.D.	2.36	3.44	3.12	2.92	2.36	3.44	3
	Initial primary root length (cm)	9.81	9.86	9.83	10.60	10.08	10.25	9
	Final primary root length (cm)	25.67	29.04	19.51	22.24	24.20	23.25	32
	C.D.	4.40	4.16	3.92	5.56	4.40	4.16	3
	Number of lateral roots	9.00	11.30	11.00	9.20	11.20	11.40	11
	C.D.	5.21	2.48	4.16	3.36	5.21	2.41	4

*P = 0.01

wth Regulators on Shoot and Root Development of Cashew

A		IBA				NAA				ClPA				Control	*C.D.
75	100	25	50	75	100	25	50	75	100	25	50	75	100	0	
9.87	8.52	8.68	8.48	8.79	8.80	8.64	8.57	8.44	8.52	8.14	8.18	8.33	8.19	9.01	0.87
21.75	23.37	21.82	23.37	18.87	22.60	20.54	22.12	20.42	19.19	20.14	20.71	21.06	18.57	14.40	—
3.24	3.25	3.28	2.00	3.24	3.25	3.28	2.00	3.24	3.25	3.28	2.00	3.24	3.25	—	—
9.80	9.12	9.10	9.12	9.58	9.37	9.00	9.56	9.30	8.92	8.97	9.20	9.35	9.58	9.69	0.66
28.34	26.25	26.33	28.25	30.12	36.34	28.63	32.05	25.71	28.12	21.43	25.14	20.83	21.28	20.37	—
3.72	3.44	3.68	4.00	3.72	3.44	3.68	4.00	3.72	3.44	3.68	4.00	3.72	3.44	—	—
14.00	17.00	18.80	16.00	16.20	14.60	15.40	13.00	13.20	8.00	7.00	18.40	16.60	14.00	9.80	—
3.46	3.46	2.92	2.13	4.46	3.46	2.92	2.13	3.46	3.46	2.92	2.13	3.46	3.46	—	—
0.30	0.40	0.10	0.20	0.30	0.40	0.10	0.20	0.30	0.40	0.10	0.20	0.30	0.40	—	—
8.68	8.61	9.58	8.85	7.77	8.13	8.45	8.75	9.44	8.26	8.00	8.18	9.28	9.10	8.84	0.63
3.91	13.81	16.26	14.75	12.05	12.41	12.51	14.90	11.94	11.63	9.52	10.15	13.32	11.64	13.37	—
3.12	3.92	2.36	3.44	3.12	3.92	2.36	3.44	3.12	3.92	2.36	3.44	3.12	3.92	—	—
9.63	9.58	10.01	9.72	10.77	10.88	10.71	10.32	10.70	10.40	10.64	10.87	10.60	10.76	10.84	0.72
2.09	22.56	29.71	33.14	26.67	21.25	21.60	19.84	20.86	22.51	19.44	23.28	23.06	26.43	21.83	—
3.92	5.56	4.40	4.16	3.92	5.56	4.40	4.16	3.92	5.56	4.40	4.16	3.92	5.56	—	—
1.00	4.60	14.26	10.00	8.40	15.60	16.60	13.00	14.80	15.80	3.40	11.40	18.00	11.49	10.80	—
4.16	3.36	5.21	2.48	4.16	3.36	5.21	2.48	4.16	3:36	5.21	2.48	4.16	3.36	—	—

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Effect of *Azotobacter* Inoculant and Growth Regulators on the Growth of Cashew

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Abstract

A pot-culture trial was undertaken to study the effect of *Azotobacter* inoculant either alone or in combination with the plant growth regulators like GA and IAA on cashew. The combination of *Azotobacter* incoulant alone caused better growth of root system when compared to that due to growth regulators alone. Similarly, better shoot length was observed in treatment receiving *Azotobacter* inoculant alone. The population of *Azotobacter* in the rhizosphere was more in treatments receiving *Azotobacter* alone and *Azotobacter* plus GA indicating the establishment of *Azotobacter* in the rhizosphere upto 75 days of plant growth.

Introduction

Cashewnut (*Anacardium occidentale* L.) establishes fairly well in marginal lands and infertile soils. Cashew being a hardy plant comes up well in plains as well as in hilly tracts upto 700 m altitude. Good root and shoot systems are essential for the establishment of cashew seedlings in arid/semiarid regions and induction of better root system by plant growth regulators might be beneficial in establishing the seedlings.

Though much information is available on the beneficial effects of *Azotobacter* on crop plants (Sundara Rao et al. 1963; Patel, 1969; Mishustin, 1970; Brown, 1974; Oblisami, Natarajan and Balaraman, 1976) information on the bacterization of seeds of perennial plants like cashew with *Azotobacter* is scanty. The present paper deals on the effect of *Azotobacter* inoculant either alone or in combination with plant growth regulators like Gibberellic acid (GA) and Indole Acetic Acid (IAA) on rooting and other characteristics of cashew.

Materials and Methods

Cashew seeds of uniform age and weight, obtained from the Cashew Research Station, Vridhachalam, Tamil Nadu, were soaked for 30 hr in aqueous preparations of 100 ppm GA and IAA whereas the seeds soaked in distilled water served as control. Before sowing, the treatment solutions were decanted and seeds washed with distilled water. The seeds were treated with *Azotobacter* inoculant wherever required. Approximately 50 g of peat soil based inoculant mixed in jaggery solution was used for treating the seeds which were allowed to have a thorough coating of the inoculant.

Six seeds were sown in 30 cm diameter pots and irrigated with tap water periodically. Observations were made on the germination of seeds, shoot and root length, and number of lateral roots formed. The population of *Azotobacter* in the rhizosphere of cashewnut seedlings were recorded at periodical intervals.

Results and Discussions

Maximum percentage of germination of the cashewnut was recorded in water soaked control (92%) followed by *Azotobacter* plus GA (87%). The treatments *Azotobacter* alone, and IAA had same effect on germination (Table 1).

TABLE 1. **Effect of *Azotobacter* Inoculant and Plant Growth Regulators on Germination of Cashew Seeds**

Treatment	*% of Germination*		
	19*th day*	25*th day*	30*th day*
Control (Water soaking)	35.1	85.2	91.8
IAA–100 ppm	10.0	76.8	83.5
GA–100 ppm	20.0	75.2	83.5
Azotobacter alone	16.7	73.5	83.5
Azotobacter + IAA–100 ppm	13.4	76.8	83.5
Azotobacter + GA–100 ppm	31.7	78.5	86.8

Azotobacter inoculant alone casued better growth of the root system and among the plant growth regulators GA induced better root growth over IAA (Table 2). The better root formation by GA is in conformity with the earlier reports by Richardson (1958) and Shanmugavelu (1969) with different plant species. Better root growth of the cashew seedlings due to *Azotobacter*

TABLE 2. **Effect of *Azotobacter* Inoculant and Plant Growth Regulators on Shoot and Root Growth of Cashew**

Treatment	*Root length (cm)*				*No. of lateral roots formed*				*shoot length (cm)*			
	30*th day*	45*th day*	60*th day*	75*th day*	30*th day*	45*th day*	60*th day*	75th *day*	30*th day*	45*th day*	60*th day*	75*th day*
Control (water soaking)	18.0	30.2	43.2	45.6	42.0	57.6	102.2	99.8	16.4	24.4	24.8	25.6
IAA–100 ppm	10.0	31.4	50.1	46.7	27.7	64.2	74.6	68.0	10.2	24.8	25.6	26.5
GA–100 ppm	14.0	33.0	42.4	51.7	39.5	61.5	87.0	66.0	15.4	23.7	26.4	27.6
Azotobacter alone	22.0	37.6	50.2	57.6	58.7	82.6	108.0	61.4	16.5	33.0	24.9	25.5
Azotobacter + IAA–100 ppm	27.0	30.6	47.0	53.8	55.6	75.0	87.5	48.7	14.5	22.5	21.2	24.4
Azotobacter + GA–100 ppm	30.2	38.6	40.3	45.4	92.2	90.4	84.0	80.2	16.5	23.2	25.5	26.4

inoculant is in agreement with the earlier reports by various workers on crop plants (Brown, 1974; Oblisami, Natarajan and Balaraman, 1976). *Azotobacter* alone and *Azotobacter* plus GA induced more number of lateral roots in the early phase of the plant growth i.e. between 45th to 60th day (Table 2), which will be highly beneficial for the establishment of the seedlings in the main fields.

The shoot growth in the treatments receiving *Azotobacter* inoculant was more or less similar to that of the treatments receiving IAA and GA indicating that *Azotobacter* inoculant caused the same effect as that of IAA and GA and this might be probably because of the possibility of synthesis and excretion of IAA and GA in the root zone as reported by Brown (1974) in various other crops. The combination *Azotobacter* and GA or IAA did not cause much variation in the shoot growth (Table 2).

The population of *Azotobacter* on the seed just before sowing indicated that the plant growth regulators (both IAA and GA) had some what deliterious effect on *Azotobacter*, IAA being more harmful than the GA (Table 3). The possibility of seed exudates being toxic to the *Azotobacter*, is to be assessed. Such an effect was not observed in other plant systems.

TABLE 3. **Population of *Azotobacter* on Cashew Seeds Under the Influence of Growth Regulators**

Treatment	*Azotobacter population in* 10^5	
	Population/seed	*Population/g seed*
Azotobacter alone	71.5	13.0
Azotobacter + IAA–100 ppm	39.5	8.7
Azotobacter + GA–100 ppm	62.0	17.2

The data on population of *Azotobacter* in the rhizosphere and R: S ratio are presented in Table 4. Azotobacter population was more in the treatments receiving *Azotobacter* alone and *Azotobacter* plus GA, resulting in better R: S ratio throughout the study. This indicated that *Azotobacter* when introduced along with the seed, have established in the rhizosphere of cashew upto 75th day and probably they might be very active in the rhizosphere soil and thereby resulting in the better growth of the seedlings. The treatment IAA showed not much encouragement to the population of *Azotobacter* either of native or introduced cells in the rhizosphere. The

TABLE 4. **Effect of *Azotobacter* Inoculant and Plant Growth Regulators on Population of *Azotobacter* in the Rhizosphere of Cashew Seedlings***

Treatment		*Azotobacter population* (10^4/*g soil*)				*R: S ratio*			
		30*th day*	45*th day*	60*th day*	70*th day*	30*th day*	45*th day*	60*th day*	70*th day*
Rhizosphere soil									
Control (water soaking)	T_1	63.0	83.7	23.4	30.0	3.2	12.8	6.1	10.2
IAA–100 ppm	T_2	71.0	65.1	52.4	52.0	3.6	9.9	13.7	17.7
GA–100 ppm	T_3	103.0	70.7	100.4	133.3	5.3	10.8	26.4	45.4
Azotobacter alone	T_4	150.0	87.4	192.0	155.2	7.7	13.3	50.5	39.3
Azotobacter + IAA–100 ppm	T_5	127.0	62.5	70.8	112.6	6.5	9.5	18.6	38.4
Azotobacter + GA–100 ppm	T_6	148.0	146.6	156.8	110.0	7.6	22.4	41.2	37.5
Non-rhizosphere soil		19.4	6.5	3.8	2.9	—	—	—	—

*Mean of 3 replications

GA treatment alone encouraged better colonization of native *Azotobacter* cells in the rhizosphere.

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Discussion

M. Aravindakshan: How do you account for the better root development by the application of GA in association with *Azotobacter?*

G. Obliswamy: *Azotobacter* is known to synthesise growth promoting compounds like IAA, GA and GA like compounds and releases into the environment. This might be responsible for the better root development by the application of *Azotobacter* inoculants.

K. Jeevaratnam: If you give *Azotobacter* treatment in the nursery will it affect the hardening or acclamatization of the seedling?

G. Obliswamy: Seed treatment with *Azotobacter* will give better seedling (superior seedling). *Azotobacter* has been found to acclamatise the rhizosphere environment of the cashew upto 75 days after seed treatment. Further, by dipping the root system in *Azotobacter* slurry before transplanting, additional load of the *Azotobacter* cells may be made available and they might survive in the rhizosphere region. However, detailed studies are needed.

A Rapid Non-Destructive Method of Estimating Leaf Area in Cashew

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Abstract

A rapid non-destructive method to estimate leaf area in cashew is proposed based on linear measurements of leaf. The exponential model involving maximum length and maximum breadth gave the best prediction equation $A=(0.8356)\ L^{0.843}\ B^{1.08}$ with R^2 as high as 98.92 per cent. Since this model involved cumbersome computation it is preferable to use a linear model $A=0.21 + 0.69\ P$ where P is the product of length and breadth of leaf. This model also has sufficiently high predictability ($R^2 = 96.81\%$). Rapidity of this method can be further expedited without loss of predictability ($R^2=89.62\%$) by taking the linear model $A= -44.28 + 14.32\ B$ where breadth alone is taken into consideration in estimating the leaf area.

Introduction

Leaf area measurements are very often required in botanical and chemical studies. Several methods for estimating the area of leaves have been developed in various crops (Asomaning and Lockhard, 1963; Bhan and Pande, 1966; Hoffman, 1971; Krishna Marar and Papachan, 1964; Marshal, 1968; Mckee, 1964; Reynolds, 1971; Sepaskhash, 1977; Wiersma and Bailey, 1975). No such attempts have been made in cashew. The present study was taken up for developing prediction equations for estimating the individual leaf area of a cashew plant.

Materials and Methods

Twenty healthy and bearing middle aged cashew trees were selected and twenty leaves from each tree were collected at random to cover all the sides of the plant. Actual leaf area of individual leaf was determined by using a Planimeter. For the non-destructive procedure of estimation of leaf areas, modelling prediction equations by regression analysis was attempted. The following three methematical models were tried:

(i) $Ai = a + b\ Li$ where Li is the maximum length of i^{th} leaf.
(ii) $Ai = a + b\ Bi$ where Bi is the maximum breadth of i^{th} leaf
(iii) $Ai = a + b\ Pi$ where Pi is the product of Li and Bi

Further to test the adoptability, another set of 25 trees were sampled uring the same season in a different year. In all 99 leaves were randomly ollected from all the directions of the canopy. This time the actual af area was measured using a LI–Cor Electronic Area Meter. In addition the models worked *in set I following two models were also included.*

(iv) $Ai = a + bi\ Li + b2\ Bi$

(v) $Ai = a + Li^{bi}\ Bi^{b2}$

lts and Discussion

The leaves sampled were with the length ranging between 8–16 cm and dth from 5–10 cm. The models along with their multiple correlation ficient R^2 (predictablility of the model) for both the sets are given in ollowing table.

*SET I**		*SET II***	
Model	R^2	*Model*	R^2
$A = -37.75 + 8.24\ L$	89.32%	(i) $A = -36.51 + 7.61\ L$	88.84%
$A = -44.28 + 14.32\ B$	89.62%	(ii) $A = -37.86 + 15.17\ B$	89.30%
$A = 0.21 + 0.69\ P$	96.81%	(iii) $A = 2.85 + 0.686\ P$	96.45%
		(iv) $A = -52.98 + 3.72\ L + 10.16\ B$	97.35%
		(v) $A = (0.8356) \cdot L^{0.843}\ B^{1.08}$	98.92%

a planimeter conducted during September, 1972

[illegible]

The regression equations obtained by Planimeter (Set I) and Electronic Area Meter (Set II) were tested for their coincidence (Chakravarthy, Laha and Roy, 1967) and found identical as Fcal = 0.83. It was therefore concluded that the area of an intact leaf can be best estimated by the exponential model $A = (0.8356)\ L^{0.843}\ B^{1.08}$ possessing maximum predictability

($R^2 = 98.92\%$). However this may involve too much of cumbersome computations. A simple model with comparatively higher predictability ($R^2 = 95.81\%$) namely a linear model $A = 0.21 + 0.69\ P$ (where P is the product of length and maximum breadth) may be adopted.

Wiersma and Bailey, (1975) have reported that considerable time could be saved by measuring length or breadth alone of a intact leaf for estimating the area. By considering the linear model $A = -44.28 + 14.32\ B$ where B is the maximum breadth of the intact leaf of cashew plant, it is possible to estimate the leaf area with reasonable predictability ($R^2 = 89.62\%$).

Acknowledgement

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VEGETATIVE PROPAGATION

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Vegetative Propagation of Cashew-Review of Work Done in Kerala

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Abstract

Studies to find out most effective method of vegetative propagation of cashew were in progress since 1952 in Kerala. In the early trials, budding, side grafting and propagation by cuttings did not succeed. Air-layering and inarch grafting were highly successful and among these two methods, the former was simpler and cheaper. Eventhough 80–100 per cent success was obtained during November - April, the post separation mortality of layers was very high. Application of IAA – 250 ppm improved root growth in layers. The non-flowered shoots gave higher percentage of rooted layers than the flowered shoots. There was no difference in the four rooting media tried. In three year old plants, the layers showed better root system than the seedlings. Rooting of air-layers was correlated with shoot growth cycles and the establishment was better when the layers were planted in polythene bags, with made up soil supplied with Hewitt's nutrient solution.

Cashew (*Anacardium occidentale* L.) is a highly cross pollinated crop and the seedling progenies show great variability in most of the economic characters. Standardistaion of an effective method of vegetative propagation of the selected genotype is essential if the benefits of selection is to be derived by the growers. Therefore, studies to find out the most effective method of vegetative propagation of cashew were initiated from the very beginning of the cashew research programme in the State, which commenced at Kottarakara in 1952.

Trials were conducted on the different methods of vegetative propagation viz. budding, inarch grafting, side grafting, propagation by cuttings and air-layering. Among the above mentioned methods, air-layering and inarch grafting were succeessful. Since air-layering was the simplest and the most successful method, further studies were concentrated on the standardisation of this method.

Shoots of the previous season's growth (6 – 9 months old) were selected and a ring of bark 0.75 – 1.5 cm wide was removed at a point about 25 cm from the tip and a knot with twine was made in the middle of the ringed portion to prevent the reunion of the bark. Moist earth with cowdung was used as the rooting medium and gunny piece for wrapping in the earlier trials; but these were replaced by a mixture of sand and saw dust (1:1) and alkathene film respectively. The layers were ready for separation in about three month's time.

In trials conducted in 1954-55, November to April was found to be best time for air-layering, giving 80–100 per cent establishment. From the point of view of planting, the best time for layering was February-March, which will enable detachment of layers in May–June.

Effect of plant growth regulators on the rooting and subsequent establishment of air-layers: A trial was conducted (in 1962) with three commonly used, root inducing substance, viz. IAA, IBA and NAA, each in concentrations of 1000, 500 and 250 ppm in lanolin paste were applied just above the ringed portion. IAA in concentrations of 250 ppm gave the highest per cent of rooting and subsequent sprouting of the air-layers, higher number of roots, the length of roots per layer and the number of days from layering to root emergence was also less in this treatment (Table 1).

TABLE 1. **Effect of Growth Regulators on the Rooting of Air-Layers**

Treatment		*% of layers*		*Average No. of roots per layer*	*Average length of primary roots per layer*	*No. of days from layering to emergence of roots*
		Rooted	*Sprouted*			
IAA	1000 ppm	60	54	7.1	2.4	24
IAA	500 ppm	86	64	7.7	2.8	22
IAA	250 ppm	94	74	9.7	3.6	16
IBA	1000 ppm	80	62	6.7	2.4	32
IBA	500 ppm	80	56	7.1	2.4	24
IBA	250 ppm	76	62	6.4	2.7	20
NAA	1000 ppm	80	62	5.4	3.3	37
NAA	500 ppm	84	68	6.9	2.5	21
NAA	250 ppm	76	68	5.4	2.9	21
Control		86	66	5.5	2.6	22
C.D. at 5 %		..	..	1.57	0.20	..

Study on the different methods of reducing the post-separation mortality of air-layers has shown the beneficial effects of IBA 250 ppm and NAA 500 ppm by better rooting and establishment of air-layers. Keeping the separated layers under mist conditions and gradual hardening gave 72 per cent establishment as compared to 55 per cent without mist.

Effect of the age of parent tree and the type of shoot on rooting of air-layers: Layering was done on trees of three age groups viz. over 20 years, 5 years and 3 years and in each of these groups flowered and non-flowered shoots were used, adopting a split-plot design. Age of the parent tree had apparently no effect on the extent of rooting of air-layers. However, non-flowered shoots gave a significantly higher percentage of rooting than flowered shoots. Rao and Rao (1957), observed that the age of the parent tree had some influence on the rooting of air-layers. They also found that one year old shoots were better in rooting as compared to the current season's growth.

Effect of different rooting media and the thickness of the shoots on the rooting of air-layers : The trials consisted of four different media viz. sand and saw dust (1:1), wood shavings, vermiculite (coarse) and vermiculite (fine) as the main treatments and three types of shoots viz. thick shoots – having a girth of 4 cm and above, medium shoots – having a thickness of 3 – 4 cm, thin shoots – below 3 cm as the sub-treatments. There was no difference between the four media tried. The layers from the thick shoots were found to be more vigorous in growth during the first year of orchard life.

Defoliation trial : In a trial conducted in 1959, out of the 46 layers rooted and planted in bamboo baskets, 23 had their leaf lamina cut off 2 weeks before separation and the remaining 23 layers had their leaves intact. Under the defoliated group, 16 sprouted as compared to 5 only in the latter group.

Root system of layers and seedlings : Data on shoot and root development of the layers and seedlings of four age groups viz. 6 months, 1 year, 2 years and 3 years were given in Table 2. At the end of three years, the layers were almost at par with the seedlings in respect of depth of root and thickness of the main root while the layers were markedly better than the seedlings in the spread of the shoots, length of the main root, number of secondary roots and the spread of the roots. The seedlings were taller and had slightly higher girth at the collar than the layers. On the whole, the layers had a better shoot and root systems than the seedlings at the end of three years growth.

Inarch Grafting : Inarch grafting on four months old seedling root-stocks were found to be successful. Best time for inarching was January-February and July to October with 80–100 per cent success. However, from the point of view of right season for planting, grafting in January-February was the best.

TABLE 2. **Shoot and Root-growth of Seedlings and Air-Layers of Different Age-groups**

	6 months		1 year		2 year		3 year	
Particulars	*Seedlings*	*Layer*	*Seedlings*	*Layer*	*Seedlings*	*Layer*	*Seedlings*	*Layer*
Shoot								
Height of shoot from collar (cm)	35	40	94	76	174	181	215	172
Shoot spread (cm)	..	..	22x11	33x15	66x39	129x61	165x108	195x139
Girth at collar (cm)	3.0	3.8	6.5	6.0	12.3	11.5	22.5	20.5
Root								
Depth of root (cm)	7	6	12	22	32	38	38	39
Thickness of main root (cm)	2.5	2.0	4.0	3.4	6.5	9.0	9.0	8.1
Length of main root (cm)	16.5	15.0	22.4	59.0	59.0	60.0	60.0	96
No. of secondary roots	3	3	3	4	4	10	10	15
Root spread (cm)	..	..	4.5x2	17.5x4	33x5	50x34.5	100x90	108x92

Veneer Grafting, Side Grafting and Patch Budding: The highest percentage of establishment under the different methods namely Veneer grafting, side grafting and patch budding was obtained during the monsoon months from June to September.

However, these trials were conducted under nursery conditions and do not represent the field establishment.

Comparative performance of Different Types of Propagation Materials: Trials to find out the comparative growth and yield of air-layers, inarch grafts and seedlings were conducted in the different cashew research centres and the results clearly showed that the vegetative progenies were definitely more productive than seed progenies. An observational trial was laid out at Kottarakkara in 1954 to compare inarch grafts, layers and seedlings. At the end of 2½ years after planting, the inarch grafts were most vigorous in growth as compared to layers and seedlings. By third year the vegetative progenies commenced bearing while none of the seedling progenies flowered.

The Alternative: Considering the pros and cons of the different methods of vegetative propagation of cashew discussed above, the establishment of a poly-clonal seed orchard in an isolated place appears to be the best method of producing planting materials of cashew. Vegetative progenies of all the superior selections and hybrids now available may be planted in a seed garden of 50 to 100 hectares, located in isolation from other cashew trees. The seeds produced in this garden will be largely hybrid seeds, derived from natural cross-pollination and between superior genotypes. Apart from possessing the good characters of the superior parental types, the progenies are likely to exhibit hybrid vigour. Therefore, the programme for the production of superior planting material for cashew will be the development of "Elite Seed Gardens" for the production of clonal seed. While the immediate planting of the seed orchard may be done with the clones of the superior types now available, research may be undertaken to find the best combiners which may replace the poor types in the seed garden.

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Discussion

P.M. Kumaran: "Layers had a better root system then the seedling." If that is the case, what is the reason for poor establishment of air-layers in the field.

V.K. Damodaran: The mortaiity of the air-layers is mostly after separation and planting in bags or in the field. The better root systems mentioned is that of the established plants aged 3 to 4 years.

R.C. Das: (1) Have you studied the forcing of cashew shoots to root under mist? (2) Do you think that better root promotion of cashew cuttings with growth stimulating substances under mist will be a quick method of multiplication of planting materials. (3) What should be the best age of root stock plant and the scion shoot for higher percentage of success by side grafting method.

V.K. Damodaran: (1) Hardening of air-layers by heeping, then under the mist and exposing them to the atmospheric conditions aternately have showed that the establishment of the layer was markedly improved by this treatment. (2) The growth regulators are beneficial in better rooting and development only at the time of layering. No mist conditions were given. (3) The root-stock for side-grafting should have minimum pencil thickness and if it is of about 3 years, the 'take' may be quite high. About one year old seedlings may be best stock for side-grafting.

A. Ramadasan: The best result of effect of auxins on rooting of air-layers was obtained with the lowest concentration used by you viz. 250 ppm IAA. This necessitates trials with still lower concentration of IAA.

V.K. Damodaran: The concentration of plant regulators used for root induction is relatively high as compared to the concentration used for fruit-set. I agree with the suggestion that lower concentration should have been tried. But in this trial, the beneficial effects of the treatments were only limited. Hence the trial was not repeated.

Vegetative Propagation in Cashew-Review of Work Done at Vittal

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Abstract

Different techniques of vegetative propagation in cashew were tried with varied degrees of success at C.P.C.R.I., Regional Station, Vittal during 1977–78. The techniques tried were: (i) Veneer grafting on six month old seedlings raised in polybags, (ii) Side grafting on 3-5 year old cashew trees, (iii) Patch building on six month old seedlings raised in polybags, (iv) Patch budding *in situ* on one year old shoots in adult trees, (v) Air-layering, (vi) Mound layering, (vii) Cleft-grating on 8-10 month old seedlings raised in polybags, (viii) Whip-grafting on 8–10 month old seedlings raised in polybags, (ix) Stone-grafting on 40–45 days old seedlings and (x) Stem cuttings. The technique of air-layering was significantly superior over other techniques during the period of March to May. The techniques, side grafting (June, July and October) and patch budding *in situ* (April, May and June) were at par. Veneer grafting and patch budding tried on six month old seedlings raised in polybags did not give encouraging results. In mound layering trials 64 per cent of shoots struck roots and 72 per cent of them had established in polybags. The percentage take in cleft grafting was high in September (58%) followed by 54 per cent in August while the success in whip grafting being 44 and 40 per cent in August and September months respectively. Air layers on separation from the mother tree and nursed in polybags for about three weeks when transplanted in the mainfield established upto 94 per cent. Similarly veneer grafts and budded plants gave 92 and 80 per cent establishment in the field.

Introduction

With a view to determining the relative efficacy of different methods of vegetative propagation and to find out the optimum period for each method, trials were carried out for one year at C.P.C.R.I. Regional Station, Vittal during 1977-78. Different vegetative propagation techniques tried were (i) Veneer-grafting on six-month old seedlings raised in polybags, (ii) Side-grafting on three to five year old cashew trees, (iii) Patch budding on six-month old seedlings raised in polybags, (iv) Patch budding *in situ* on one year old shoots, (v) Air-layering, (vi) Mound layering, (vii) Cleft-grafting on 8–10 months old seedlings raised in polybags, (viii) Whip-grafting on 8–10 months old seedlings raised in polybags, (ix) Stone-grafting on 40–45 days old seedlings and (x) Stem cuttings.

Materials and Methods

Seedlings raised in polybags of 45 x 30 cm of 500 gauge with uniform vigour and thickness of stem were used for grafting by veneer method. To ensure uniformity of age of stock plants, monthly sowings of seednuts were taken up six months earlier to the commencement of trial. Every month hundred seedlings were worked upon.

Side grafting was done on 3 – 5 year old cashew trees with a stem girth ranging from 20 to 35 cm using hundred dormant terminal scion shoots every month.

Well matured one year old shoots with grey coloured bark were selected as bud-wood for grafting. The selected bud-wood, before being severed from the mother tree was precured by cutting the leaf blades of the shoot into halves and leaving them as such, for about a week to activate the auxiliary buds.

In air-layering trials, every month hundred air-layers were made, selecting shoots from the trees of the same age group and vigour. The data on percentage of rooted layers obtained every month and number of days taken for separation, percentage establishment in the field were recorded.

To study the scope of mound layering fifteen adult trees of cashew were subjected to stooling in February 1978 and the shoots emerged from the stumps were covered with a mound of sand in May 1978 for etiolation. The basal portion of the etiolated shoots of about pencil thickness were cinctured and the upper portion of the ringed area was treated with IBA for quick rooting and covered back with sand. The shoots were observed for rooting in August 1978 and the rooted ones were separated and planted in polybags for establishment. The process of cincturing the available shoots and separating the rooted shoots was repeated twice in September and November during nine months in 1978 and the total production of ground layers was worked out.

To find out the response of different techniques of grafting in cashew viz. whip-grafting and cleft-grafting, an observational trial was laid out. The grafting were done on 8 – 10 month old cashew seedlings raised in polybags.

Germinated seednuts, about 45 days age with purple plumule growth were used for seed grafting. The precured scion was trimmed to a wedge shape and inserted into the slit made in the centre of the stock by cutting off the plumule growth horizontally. On matching the cambial layers of both the stock and scion, the joint is gently wrapped with a plastic film. The seednuts on grafting were resown in small polybags for further nursing.

For propagating cashew by stem cuttings, a preliminary study was conducted using mature brown coloured stem cuttings of about 20 cm length with leaf blades half cut. The cuttings were slightly split open at the basel end before treatment with IBA 100 ppm solution for six hours. The treated cuttings were planted in polybags (30 x 10 cm) filled with sand and kept in mist chamber for rooting. The cuttings were observed for rooting after 40 days.

Results and Discussion

Among the first five techniques of vegetative propagation listed above air-layering was significantly superior (46%) over the other methods. Side grafting *in situ* (25%) and *in situ* patch budding (23%) on one year old shoots gave encouraging results and these two techniques stood at par (Table 1).

Contrary to the results obtained with *in situ* grafting and budding, the success with veneer grafting and patch budding done on six month old seedlings raised in containers was dismal.

The seasonal influence on the success with different techniques was marked. The summer season (March-May) during which period the cashew trees are in active growth with new flush and flowering in the west coast was found suitable for air-layering to secure high percentage (74 – 79%) of rooted layers. This is indeed an added advantage since the layers would become ready for planting at the right season to ensure better establishment.

Late summer and early monsoon period (April - June) was found to be encouraging for *in situ* patch budding and during this period, the trees will be in active growth and this facilitates early sprouting of buds soon after grafting on to the stock.

The humid conditions during monsoon (June – October) and the availability of scion material are the two important factors responsible for optimum success with both veneer grafting and side grafting techniques. A maximum success (72%) with side grafting *in situ* was obtained in July followed by June (52%) and almost the same trend was observed in veneer grafting. Grafting in cashew has a limitation due to non-availability of required stage of dormant terminal shoots all round the year. The scope thus, for taking up intensive grafting on commercial scale found to confine to about 5 – 6 months period (June - November) only in an year. The success achieved with other methods of grafting like cleft and whip grafting has also confirmed the fact that the monsoon period is congenial to take up any method of grafting involving the usage of dormant terminal shoots of cashew as scion material to secure optimum success.

TABLE 1. **Percentage Means* of Success in Five Different Vegetative Propagation Techniques in Cashew (1977-78)**

Technique	1977					1978							*Mean*
	Aug.	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June*	*July*	
1. Veneer grafting in polybags	17.7	9.2	44.8	18.0	11.6	0.4	4.8	Nil	Nil	14.1	39.9	31.3	14.4
2. Side grafting *in situ*	38.0	43.0	52.4	1.2	15.4	24.6	Nil	Nil	Nil	Nil	51.8	71.7	24.8
3. Patch budding in polybags	3.8	2.3	2.6	5.9	11.0	6.9	1.1	6.0	3.5	1.0	11.0	14.9	5.9
4. Patch budding *in situ*	Nil	Nil	9.7	13.8	19.9	17.9	24.3	30.6	33.4	59.1	44.5	27.0	23.3
5. Air-layering	26.6	10.3	14.0	51.0	39.8	59.1	43.0	79.1	74.2	76.6	42.0	38.1	46.1
Mean	21.4	16.2	30.8	22.5	24.4	27.2	18.3	29.1	27.8	37.7	47.3	45.7	..

SE for months = 1.64; SE for techniques = 0.78; SE for M x T = 17.27
LSD (P=0.05) Months - 4.72; Techniques - 2.4
*The data were analysed in strip-plot design with arcsin transformation.
Table of means were presented after backward transformation.

A maximum of 53 per cent success was obtained with cleft grafting done in September followed by 50 per cent in August. The success in whip grafting varied from 18 to 25 per cent during June, August, September and October months and thus, the success achieved on higher side was confined to humid period (Table 2).

TABLE 2. **Success of Cleft Grafting and Whip Grafting Done on 8 - 10 Month Old Seedlings Raised in Polybags During 1977-78.**

Month	*% success*	
	Cleft grafting	*Whip grafting*
August, 1977	50.0	18.0
September, 1977	53.0	23.0
October ,1977	34.0	25.0
November, 1977	Nil	Nil
December, 1977	6.0	14.0
January, 1978	5.0	7.5
February, 1978	Nil	Nil
March, 1978	Nil	Nil
April, 1978	Nil	Nil
May, 1978	Nil	Nil
June, 1978	4.0	22.5
July, 1978	10.0	4.0

(Desirable dormant terminal scion shoots were not available from November to May)

The preliminary studies made to propagate cashew through stooling and layering gave encouraging results. Out of 307 shoots treated in three different spells, 62 per cent of shoots had struck roots of different sizes and when these shoots were separated and planted in polybags for establishment, 61 per cent of them had survived.

Propagation of cashew by stooling and layering may be economical since no wrapping material, saw dust or moss are required as in case of air-layering. Further, ground layering is risk-free since they are not subjected to any damage due to strong winds. There is a likelyhood of producing one lakh layers from an hectare of land in an year, if the planting is done initially at one metre distance with promising clonal progenies.

Conclusions

1. It is possible to multiply high yielding cashew trees by vegetative means adopting air layering method all round the year, especially when the trees are in flush and bloom (March-May) to secure high per cent of rooted shoots and better establishment of layers in monsoon under the conditions available at Vittal in the west coast of India.

2. There is a vast scope to improve unthrifty cashew trees either by side grafting with superior scion terminal shoots or through patch budding *in situ*.

3. The studies made with regard to field establishment of clonal progenies raised in containers gave an indication that they would establish equally well as of seedling progenies when transplanted.

Acknowledgement

I am grateful to Dr. N. M. Nayar, Director, Central Plantation Crops Research Institute, Kasaragod, for the invitation extended to present this paper at International Cashew Symposium.

Discussion

R.T. Gunjate: You have tried stone grafting in cashew on 40–45 day old seedlings. Did you try grafting on very young seedlings say 8–10 days old? In mango the maximum success in stone grafting is obtained on such very young seedlings.

S. Nagabhushanam: The suggestion is most welcome. Stone grafting will be tried on comparatively young seedlings.

S.S. Das: The results obtained during the different months of the year with the various methods of vegetative propagation have been discussed. The climate varies in the different cashew growing areas during the same month. Will it, therefore, be possible to correlate these results with the various climatological factors like precipitation, humidity, temperature, etc. or with growth periods so that the results will be universally applicable?

S. Nagabhushanam: The trees when in flushing and flowering would give high percentage of rooting when layered.

R.C. Das: As compared to side grafting in general, budding is not very successful in cashew. Studies at Bhubaneswar have shown that "T" budding had poor response. Is there any method to increase the success by budding, since higher economic utilization of scion material could be possible by this method?

S. Nagabhushanam: Patch budding can be tried with the stock of different thicknesses. It is true that it will be more economical to resort to budding for effective utilization of scion material.

Vegetative Propagation of Cashew - Review of Work Done at Bapatla

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Abstract

Air-layering with saw dust as the rooting medium gave 100 per cent rooting during monsoon months. In the rainy season callusing (10 days) and root initiation (25 days) were faster as compared to other seasons. Ground layering was equally successful in rainy season. Although inarching gave 52 to 96 per cent success from July to December on seven months old seedlings, graft union was defective. Among the various methods of budding, patch budding was successful in 41 per cent cases. There was no success with side grafting while veneer grafting on seedlings gave 96 per cent success in July and complete failure in May. Vegetative propagation in cashew through stem and root cultings was not successful.

Introduction

Cashew *Anacardium occidentale* L. being highly heterozygous crop, exhibits varied fruit and vegetative characters. Yield potential of the trees also varies very much. For the production of plants with uniform characters, experiments in vegetative methods of propagation of cashew were in progress at Cashew Research Station, Bapatla since 1957. The various methods tried and the extent of success achieved are dealt with individually.

Air-layering : Generally moist sphagnum moss is suggested as a rooting medium for air-layering which is expensive and is not locally available. Hence, a few cheap materials that are locally available were tried as media and their utility assessed. Among the different media used (viz. saw dust, sand, red earth, paddy husk and black earth) saw dust and sand were found to be the best.

In a trial on the air-layering in different months success ranged from 70 to 90 per cent between May and September and 67 to 53 per cent between October to April. The callus and root formation are confined to the distal cut end of the twig. Removal of a full ring of bark is slightly better than two half rings made from opposite directions. Success in the air-layering appears to be more when the tree is in the resting phase than during the period of growth, or reproduction. Success is more associated with rainy and warmer period than with dry and winter months.

It was observed that it took 10 to 15 days to callus during resting period of the tree and when there was rainfall, and it took 20 days to callus when the tree was in flushing, flowering or fruiting stage. The time taken for root production varied from 25 to 40 days. It was also observed that it took shorter time for callusing and root production during the rainy period of the year than during the dry period.

Ground layering : Branches about an inch thick trailing near the ground were pressed into the soil to induce rooting. Experiments in ground layering were conducted on similar lines of air-layering. There was profuse rooting in layers from June to October with an average success of 84 per cent. Rooting took place in 20 to 30 days and layers could be separated in 60 days in rainy months. Callus and rooting were observed only at the incision towards the apical side. Relative efficiency of ground and air-layering in different periods of the year is presented below:

Method	*Success in percentage*		
	July to Oct.	*Nov. to Feb.*	*Mar. to June*
Ground layering	81.75	54.25	49.50
Airl-ayering	78.00	62.00	73.00

Cashew can be propagated by ground layering during the first monsoon utilising the low hanging branches. Air-layering can be adopted during the other period when the success is not less than 60 per cent. Thus, air-layering can supplement ground layering.

Inarching using seven month old seedlings as rootstock : Seeds were sown in pots and those that attained graftable size and thickness were used in this trial. There is high percentage of success (52 to 96%) from July to December, due to high humidity and rainfall in these months, while in the rest of the months it was around 24 per cent. Though relative humidity is low in July and September the high percentage of success is probably due to rains and high humidity that prevailed in succeeding months. Success also seems to be associated with the resting period of the tree.

Budding : To evaluate the possibility of exploiting budding as a nursery practice in cashew, twenty five insertions by the shield method (inverted T) were made. No success was observed in any month.

Further attempts consisted of: (i) Budding with a shield of bark without any sliver of wood attached to the bark, (ii) Instead of shield budding, ring, flute, forkert, modified forkert and Yema budding were tried, (iii) A bigger shield with the bud was used. But none of the methods were success ful. Attempts at patch budding were successful when bud part was provided with a flap of banana sheath. Success was 41 per cent in June-July while 36 and 32 per cent of success were recorded in August and September respectively.

Experiments with stem cuttings: The trials to induce rooting in stem cuttings through different methods met with no success. The methods used were: (a) cuttings of different ages, (b) different thickness, (c) pre-callused shoot cuttings and (d) the use of growth regulators like Seradix B2, IBA and IAA.

Veneer grafting: Veneer grafting can be considered a promising practice of vegetative method of propagation for cashew, offering considerable success when done between June to October in six months old seedlings.

Side grafting: Eventhough various techniques of side grafting were tried none of these were successful under Bapatla conditions.

Vegetative Propagation in Cashew - Work Done at Vridhachalam

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Abstract

The propagation trials conducted for a decade at Cashew Research Station, Vridhachalam indicated that 40–50 per cent success can be achieved in air-layering one year old shoots of cashew during July to September. IBA at 500 ppm gave higher percentage of rooting. In patch budding the highest percentage success (71 %) was recorded in July. In all the months the buds took about 25 days for sprouting.

Cashew is an important cash crop with an area of 1,02,700 hectares in Tamil Nadu. Being a highly cross pollinated crop, the performance of seedlings is uncertain and variable, resulting in low yields. Thus the need to resort to some method of vegetative propagation was much felt. Inarching, air-layering, side grafting, nurse grafted Y – cutting methods have been reported and recommended by various research workers (Rao and Rao, 1956 and 1958; Rao, Rao and Rao 1957).

The experiments carried out at Bapatla (Andhra Pradesh), Vengurla (Maharashtra) and Anakkayam (Kerala) revealed that cashew can be propagated by approach grafting, ground layering and air-layering. In Vridhachalam a detailed study of the different methods of vegetative propagation viz. air-layering and patch budding, were undertaken in Cashew Research Station during 1972–74.

Air-layering was done in one year old and three months old shoots employing different media of sphagnum moss, coconut fibre, soil plus sand mixture and soil plus manure mixture. IBA, IAA and NAA were applied at 1000, 2000 and 5000 ppm. One hundred shoots per month were air-layered commencing from January 1972 to December 1974 and observations were made on the rooting in different media and appropriate time for field establishment.

Patch budding was done at the rate of 25 bud insertions per month for 12 months from January to December on one year old cashew seedling stocks adopting standard procedure. Observations were made on the establishment of the bud and the time taken for the sprouting.

In the air-layering trials conducted during two years (1972–73 and 1973–74), better rooting in layers was observed in July-August in 1972–73 and September-October in 1973–74. Eventhough good percentage of rooting was also noticed in other months (Jan., Feb., Oct. and Dec., in 1972–73 and Nov., 1973–74) the field establishment was good only in layers made during July and August (Table 1) and separated during October-November. As the field establishment is the most important aspect in the vegetative propagation trials, July and August months when the percentage of the rooting as well as field establishment is high, appears to be ideal period for air-layering under Vridhachalam conditions.

TABLE 1. **Cashew Air-Layering in Different Months.**

Sl. No.	*Month of*		*% rooting*		*% field establishment*	
	Operation	*Separation*	1972-73	1973-74	1972-73	1973–74
1.	January	April	41	12	12	17
2.	February	May	47	24	28	13
3.	March	June	19	17	47	30
4.	April	July	29	20	36	30
5.	May	August	17	12	74	67
6.	June	September	30	21	97	62
7.	July	October	50	35	94	91
8.	August	November	45	34	90	91
9.	September	December	35	58	43	40
10.	October	January	40	57	23	21
11.	November	February	38	40	16	15
12.	December	March	44	16	19	25

Rooting of air-layers in four different media used namely sphagnum moss, coconut fibre, soil plus sand and soil plus manure was comparatively good during July-October. Differences due to the type of medium used were only marginal indicating that seasonal influence is more important factor in rooting of air-layers (Table 2).

TABLE 2. **Effect of Media on Air-Layering of Cashew in Different Months**

Month	*Sphagnum-moss*	*Coconut fibre*	*soil + sand*	*soil + manure*
January	18*	4	8	8
February	29	7	5	8
March	21	2	3	3
April	33	10	24	12
May	20	4	11	8
June	25	9	11	13
July	50	21	31	34
August	38	34	31	37
September	43	34	40	35
October	30	37	33	29
November	21	11	30	19
December	19	6	9	8

*Per cent success

In the trials with growth regulators also the differences in rooting were obvious between the seasons with July-October being the best. In addition, the results with all the three growth regulators (IAA, IBA and NAA) at the concentrations tried were at par. In patch budding except during February, June and December in all the other months the success was over 30 per cent with July being the best (71 %).

In general, it appears that success in vegetative propagation in cashew is location specific and under Vridhachalam conditions budding appears to be more successful than air-layering.

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Vegetative Propagation of Cashew-Through Side Grafting *In Situ*

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Abstract

Vegetative propagation of cashew *in situ* through side grafting was successful during both spring and monsoon seasons. The effect of temperature, rainfall and humidity on side grafting was inconsistant. The correlations between success and meteorological factors could not be established. The success obtained under Orissa conditions is detailed.

Introduction

In cashew the clonal propagation is a surer way to maintain the genetic stability of germplasm which may otherwise deteriorate through seed multiplication because of the high degree of cross fertilization associated with the family Anacardiaceae.

Vegetative propagation in cashew was taken up in Orissa by Soil Conservation Organization. The method first followed was air-layering. Absence of tap root system in plants raised through air-layering and the vulnerability of such plants to strong wind, added with expensive method of maintaining the rooted layers in nursery and the inability of the layers to face adverse weather conditions in early days of planting in the field, resulted in attempting other methods of vegetative propagation like budding and grafting *in situ*. We reported in 1974 substantial success (42%) in side grafting, by grafting in stock plants of less than three years old *in situ*. Almost no success was met in other methods of vegetative propagation *in situ*, although higher percentage of success was reported by Palaniswami and Hameed (1976) in patch budding and some success in veneer grafting by Phadnis, Choudhari and Bandekar (1971), when grafted on nursery seedlings. The best grafting period was seen to be rainy season and with the onset of winter, the success progressively declined (Sahani and Patro, 1974), which restricted the grafting season only to four months in a year. Some success was also achieved by grafting in spring i.e. February to April.

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It was, therefore, considered necessary to study the relationship between environmental factors and the success in grafting.

Materials and Methods

Side grafting was done at weekly intervals in spring and monsoon seasons during 1977 and 1978 in the cashew plantations at Saradhapur and Arjunpur using stock plants planted in 1976. The stock plants selected were less than three years of age, raised from seedlings in polythene bags and planted in the field without damaging the tap root system. The bark of the stock plant was cut transversely but narrowly with a grafting knife at a height of 20 to 30 cm from ground level. Two vertical cuts of about 6 to 7 cm long were then made downwards from the two ends of transverse cut and the rectangular piece of bark thus marked was pulled down gently. The scion stick, about 15 to 20 cm long and approximately pencil thick was prepared by giving two slanting cuts, one 4 to 5 cm long on the inner side and the other 1 cm long on the outer side. The cleft of the scion was then inserted cautiously under the flap of the bark in such a manner that the slanting cut with the dormant bud at the top was kept away from the stock and tied by means of polythene tapes, so as to keep the scion in its place and not to allow rain water to enter into the grafted surface. The union took place within a month after which the top of the seedlings was given incission in stages and finally cut off when the scion started growing.

Scion sticks with 17 cm length were selected from mature terminal shoots of the current season's growth. About ten days prior to grafting the scion sticks were defoliated retaining the petioles which when fall off indiacte the readiness of the scion for grafting. Swollen condition of the apical bud is also another indication for removing the scion for grafting but once new growth starts, it is judged unsuitable. After removal from the tree, the scion stocks were kept covered with moist cloth till they were used for grafting. Attempts were made, however, to graft immediately after removal from the mother plants.

Besides, the success in grafting, weekly record on temperature, rainfall and relative humidity was also made.

Results and Discussion

Success was recorded after 20 – 30 days when scions sprout. However, the failure in grafting was obvious in a week when the scion sticks started drying up, showing wrinkled surfaces. The best time for grafting is during March and with the increase in temperature in April, the percentage success has decreased (Table 1). The low temperature condition in the very first week of February has also resulted in a lower percentage of success. However, the correlation between different meteorological factors like temperature and relative humidity and the percentage of success has not shown any significant relationship, excepting the rainfall which showed a negative correlation in spring season in 1977 and positive corrleation in 1978. The average percentage of success recorded in both the years was at par. However, the highest success recorded in 1978 was 58 per cent as against 53 per cent in 1977. This may be attributed to the fact that the average temperature experienced in 1977 was higher than that of 1978.

TABLE 1. **Meteorological Factors and Success of Grafting in Spring and Monsoon Seasons**

Season/ Month	1977				1978			
	Total R.F. (mm)	*Mean Temp.*	*Mean RH*	*% success*	*Total R.F. (mm)*	*Mean Temp.*	*Mean RH*	*% success*
Spring								
February	2.1	27.2	65	44	0.4	24.7	66	41
March	0.0	29.3	66	53	60.2	27.7	69	58
April	16.3	30.1	72	37	0.2	25.3	70	33
Monsoon								
May	21.9	32.3	69	Nil	..	..	..	..
June	267.7	30.3	78	21	..	..	..	..
July	470.2	28.5	84	54	202.0	29.0	83	56
August	318.1	28.5	87	56	213.4	28.2	85	54
September	241.0	28.8	82	54	271.4	28.7	84	53
October	134.2	28.0	76	25	63.4	28.1	81	42

Monsoon season during 1977 was extended from May to November whereas in 1978, the grafting was confined from July to middle of October. No success was obtained in May in 1977 and the same extended to June also in 1978. With the onset of winter, which is associated with low temperature, the success had also gone down. This indicates that temperature has an important role in the success of grafts. The correlation between temperature and percentage of success was negative. This result is not conclusive as the lower temperatures of winter did not help the grafting and the percentage of success has gone down. The best results were obtained when the temperature ranged between 28 to 30°C. The rainfall and relative humidity had a significant positive correlation with that of the percentage of success. But none of the meteorological factors showed any significant correlation with that of the percentage of success during 1978. This may be attributed to the fact that the rainy grafting season in 1978 was abridged from July to middle of October.

The highest percentage of success recorded was 62 per cent in the last week of July 1977 and 61 per cent in the first week of September in 1978, but the average percentage of success during 1977 was substantially low. This wide variation in the average success may be due to a very long span of the grafting season of 1977 (25 weeks in 1977 compared to 15 weeks in 1978), embracing wide variations in meteorological factors to comparatively less variations as experienced in rainy season of 1978. However, further studies on grafting throughout the year are necessary to understand the effect of meteorological factors on the success of side grafting *in situ.*

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Comparative Performance of Seedlings, Air Layers and Inarched Grafts in Cashew

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Abstract

In a 19 year old trial at the Regional Cashew Research Station, Vengurla (Maharashtra) on the comparison of seedlings, air-layers and inarched grafts raised from a single mother tree, Vengurla-1, the yield of vegetatively propagated trees was better than the seedling progenies. However, the size of the trees as judged by the volume of canopy, the seedlings were more vigorous than the air-layers and inarched grafts.

Introduction

The existing plantations of cashew which are mainly raised from seeds are heterogenous for growth and yield. To achieve uniformity in plantations several vegetative propagation techniques were tried. Air-layering is a widely known practice in cashew, but field establishment is not always satisfactory. Nagabhushanam and Murthy (1978) reported that about 90 per cent of air-layers planted have successfully established in the main field and are productive in about nine months from its planting. Susamma Cherian and Thomas Kurien (1976) also reported that the layers have given an yield of 3.5 and 4.2 kg at two and half and three and half years of age respectively.

Materials and Methods

A trial was laid out during the year 1958–59 in a randomised block design with four replications at the Regional Cashew Research Station, Vengurla in Ratnagiri District. Seedlings, air-layers and inarched grafts from Vengurla-1, a high yielding single mother tree were used as planting materials. The spacing was 9.9 x 9.9 m. The experimental place represents more or less a tropical climate with high humidity and warm weather throughout the year. The temperatures are equable with an aveiage annual rainfall of 2770 mm confined mainly to June – September. The soil at the experimental site is laterite and acidic with a pH range of 4.5 to 5.3.

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Results and Discussion

The data pertaining to the volume (recorded in June 1978) and yield per tree (1974-78) and number of nuts per kg are presented in Table 1.

TABLE 1. **Comparative Performance of Seedlings, Air-Layers and Inarch Grafts**

Progeny	*Mean yield kg/tree* (1974-78)	*No. of nuts/kg*	*Mean tree volume* (m^3)
Seedlings	11.6	171	525.5
Air-Layers	15.5	159	425.2
Inarch Grafts	14.5	163	489.5

The seedling progenies had low average yield of nuts when compared to air-layers and inarched grafts. However, in the air-layers and inarched grafts almost equal yield of nuts was obtained. The results are in confirmity with the those of Veeraraghavan and Vasavan (1977) who observed that air layers flowered earliei than seedlings and yield 44 per cent and grafts 11.6 per cent more than the seedlings. Similarly, Gowada et al. (1976) reported that in a fifteen year old trial, inarched grafts and air-layers were more precocious and their yield was much higher than the seedling trees.

The seedling progenies had the maximum canopy volume followed by inarched grafts, while it was least in air-layers. The same may be due to the better root system in seedlings and inarched grafts.

The least number of nuts (159 per kg) were recorded in case of layers and maximum nuts (171 per kg) were recorded in seedlings. The smaller size of nuts of seedlings could be due to the extreme variation in the progenies.

It can be concluded that if clonal progenies of selected mother trees having proven productive capacity are planted and proper cultural practices are followed, the per unit area production of cashewnut can be considerably increased.

Acknowledgement

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Discussion

N. Ramu: What is the amount of variation in yield in air-layered and inarched plants? As the air-layered plants are small in stature can we increase the population density per hactare?

R.T. Gunjate: The variation in yield in air-layers and inarched grafts is much less than that of seedlings. Though the volume of air-layers was smaller than the grafts and seedlings, the difference was not very large to warrent high density plantings.

Abdul Razak Abdullah: Was there any problem of anchorage since the air-layers do not have tap root? When crown became heavy where there any problems in maintaining the crop in upright position?

R.T. Gunjate: The air-layers generally tend to spread rather than growing erect.

In Vitro Propagation of Cashew for Crop Improvement

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Abstract

Multiple plantlets were induced directly without callus formation from cotyledonary fragments of Cashew (*Anacardium occidentale* L.) cultured on defined medium containing 0.5 mg/l each of IAA and kinetin. The plantlets developed within four weeks and had strong root system. The significance of this method for clonal propagation from hybrid seeds is discussed.

Introduction

Plant tissue culturists in the past decade have successfully demonstrated the totipotency of cells of many species. Large scale plant regeneration *in vitro* is now possible in a number of species (Murashige, 1974); almost all such species are herbaceous in nature. In addition, there are reports of *in vitro* regeneration in many other species where it occurs only sporadically and hence are unsuitable for mass propagation.

Cashew is highly cross pollinated species propagated through seeds, with high degree of variability between trees. Hybridisation experiments to combine prolific bearing habit with large nut size are reported to be successful (Aiyadurai, 1966). However, to propagate the proven hybrids without the loss of their yield potential a suitable rapid vegetative multiplication technique is necessary. Taking the hint from Hayes (1953), successful layering techniques are reported to have been developed for mass propagation of selected elite trees (Chhonker and Singh, 1967; Damodaran, 1970; Rai, 1970). However, plants thus raised have an inherently weak root system and the success of rooting is influenced by factors such as genomic composition, ontogenetic age of the tree, seasonal and physiological conditions.

The present report is an account of a culture technique for mass propagation of cashew directly from embryonal tissue without callus formation and thus excluding the possibility of genetic alterations, which are associated with the plant regeneration through callus (Lester and Berbee, 1977).

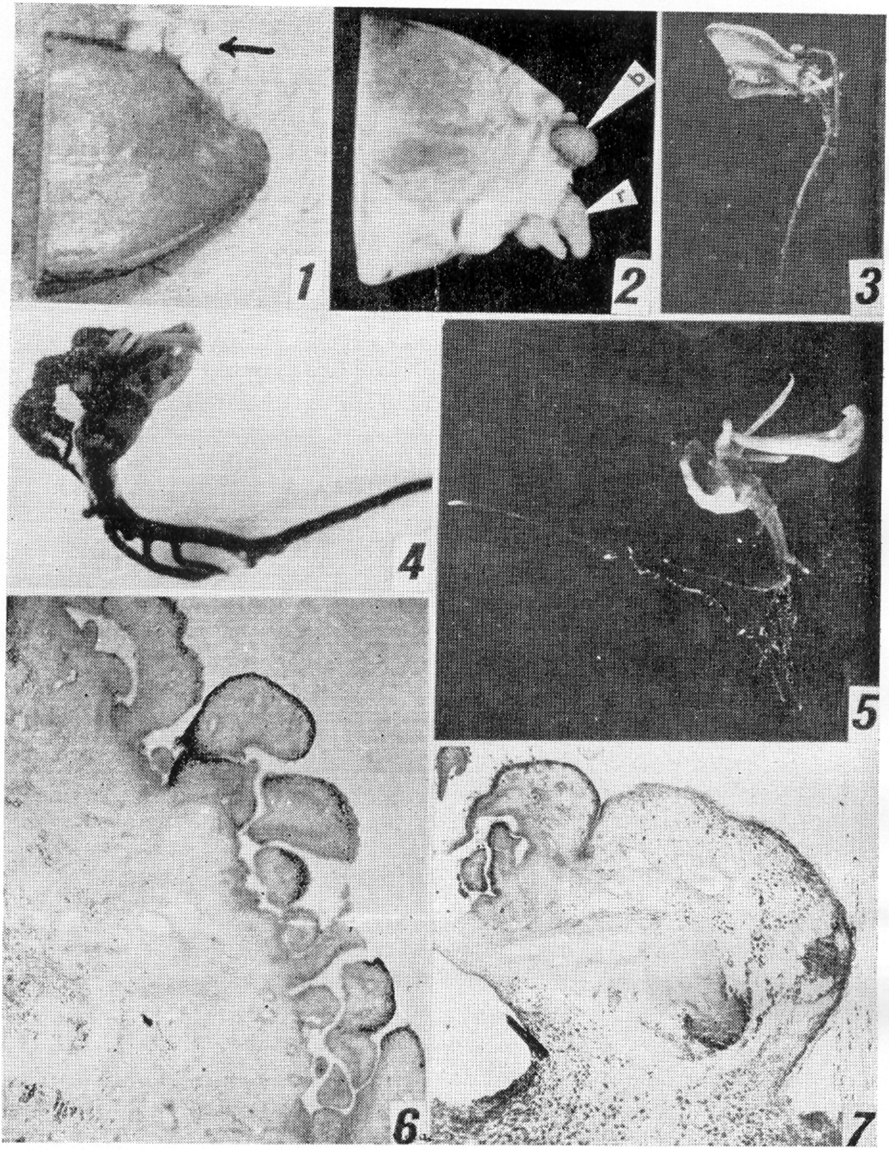

Fig. 1: A 4 mm long fragment of cashew cotyledon with a group of shoot buds (arrow) on its adaxial side X5

Fig. 2: Same showing bud (b) and slightly elongated root (r) primordia X6

Fig. 3: same at a later stage showing multiple plantlets X2

Fig. 4: same with a well formed root system for each shoot bud X2.

Fig. 5: same at a slightly older stage with perfectly balanced plantlets. X1.25

Fig. 6: Transection of the cotyledon shown in figure 3 indicating sites of origin of the shoot apical meristem X40

Fig. 7: Longisection of cotyledon showing a plantlet with shoot and root with no vascular connection to the mother tissue. X40.

Materials and Methods

Mature seeds were collected from plants growing in the Calicut University campus and stored in a refrigerator. The cashew kernel was dissected out and surface sterilized with 0.05 per cent mercuric chloride solution. Explants, fragments of hypocotyl and cotyledons of 3 – 5 mm in length were placed in culture tubes. Murashige and Skoog medium as modified by Lin and Staba (1961), containing 0.5 mg/l of IAA and 0.5 mg/l of kinetin was used. The pH was adjusted to 6.2 prior to autoclaving. After inoculation, the cultures were kept in uninterrupted darkness for 24 hours and later transferred to continuous light with an average intensity of 7000 – 8000 lux at the level of the culture rack with a temperature maintained at 24 ± 2 °C.

Tissues for histological observation were fixed in FAA, dehydrated in a tertiary butanol series, and embedded in paraplast. Sectioning was done at 10μm and the sections were stained with methyl green – pyronin B (Taft, 1951) and mounted in DPX mountant.

Results and Discussion

Two pale white and massive cotyledons constitute bulk of the mature embryo enclosing the root-hypocotyl axis and the plumule. The explanted cotyledonary and hypocotylary fragments averaged about 4 mm long. In about 6 weeks, the hypocotyl region grown on a medium containing IAA and kinetin produced one shoot bud each in two explants out of a total of 40 without any trace of root formation. The cotyledonary explants turned green and developed bumps along the adaxial surface. In about 9 days, the protruberances which developed into buds were somewhat hemispherical in outline. In 20 per cent of the explants, shoot buds were visible slightly earlier than the root primordia (Fig. 1). Visible root primordia formed in 80 per cent of the explants slightly earlier than the shoot bud primordia presented a comparatively elongated appearance (Fig. 2). Figure 3 shows a 3 mm long explant taken from the base of the cotyledon from mature seed after three weeks in culture showing ten well developed shoot buds and roots. Each such shoot was associated with a tap root (Fig.4). The explants taken from the base of the cotyledon produced healthy plantlets quicker than those from other regions of the cotyledon (Fig. 5). In transverse section of a cotyledonary explant after three weeks in culture, a number of adventitious buds were formed, each with a short apex enclosed in a pair of leaves (Fig. 6). No sign of callus formation was noticeable.

The origin and organisation of the plantlets have not been histologically studied. They appeared to have been initiated superficially on the cotyledons without any vascular connection between the plantlet and the mother tissue. Further, the vasculature between the root and shoot of the newly formed plantlet showed a slight discontinuity in earlier stages of development (Fig. 7).

Only recently the streanuous task of developing intact plants from tissues of woody plants have been attempted and success reported with less than 15 species mostly by subculturing callus tissue. Most callus cultures contain a mixed population of cells with different chromosome numbers than the original cell line so that the individuals formed from such cultures will not be copies of the original.

Embryoids (Hu and Sussex, 1971), normal shoots with buds (Winton and Verhagen, 1977) and complete plantlets (Sommer, Brown and Kormanik, 1975; Cheng, 1976) have been produced so far directly from cotyledonary tissues of only four tree species. Hus and Sussex (1971) obtained embryoids directly out of the cotyledon in *Ilex acquifolium* but with no evidence of a constricted root pole. Similar shoot bud initiation has also been reported in cultures of *Pseudotsuga menzisseii* (Winton and Verhagen, 1977). In *Tsuga heterophylla* (Cheng, 1976), plantlets were successfully established by rooting shoots from somatic cells directly in rooting medium. Sommer, Brown and Kormanik (1975) obtained complete plantlets from cotyledonary explants of *Pinus palustris* by transferring differentiated shoot apices to a medium conducive to root initiation and then to a mdeium favourable to root elongation and normal plant development indicating that shoot and root apices arise independently of each other.

The development of tap root with lateral roots in cashew cultures is in close harmony with that of the shoot development, even when the plantlet is still attached to the cotyledonary mother tissue. The vascular traces of the plantlet do not show continuity with the cotyledonary mother tissue indicating their adventitious origin; the newly formed plantlets can be severed and transferred to the soil without injury. Further more, unlike in long leaf pine, no distortion in the vascular pattern of the cotyledonary mother tissue is noticeable in cashew cultures.

The results reported herein is the first instance in which perfect plantlets have been obtained directly without callus formation from cotyledonary fragments with a well developed shoot and root system in any tree species, and the plantlets developed within a relatively short span of three to four weeks in culture.

This method of induction of perfect plantlets provides a way to establish clones of plants from embryos of hybrid origin.

Acknowledgement

The support for the research work by the Department of Science and Technology to the senior author is acknowledged.

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Discussion

A. Ramadasan: Have you tried any other parenchymatous tissue other than the cotyledonary peelings.

P. N. Unni: Our studies were concentrated on the cotyledonary tissue. We had some preliminary trials with tissues of seedlings such as hypocotyl, internodal region of the seedlings and peelings from these parts. But no successful cultures were established. This, we are sure, can be overcome with further modification of the medium by broad spectrum tissue culture experiments. The studies in these line are in progress.

P. N. Ravindran: Was there any tannin problem in your tissue culture work? If so, how did you overcome it?

P. N. Unni: In the case of cashew cotyledons, there was not much interference of tannin, though tannin was found to diffuse slightly into the medium

But we could get perfect plantlets with independent root system without even the hinderance of callus formation.

P. N. Ravindran: Did you try meristem from adult plants?

P. N. Unni: We have not so far tried meristem culture.

R. D. Iyer: If tissue culture propagation of cashew is to be envisaged as a practical proposition for rapid multiplication of elite trees, we must start with meristem or tender shoot tissues of adult trees and not cotyledonary or other embryonal tissues from true seeds, which will only give variable progeny. We, at the C.P.C.R.I. have initiated work on tissue culture in cashew using tender shoots from adult trees and have obtained a rapidly growing callus. We could overcome tannin interference by using cysteine hydrochloride or a mixture of ascorbic acid and citric acid in the medium. We are also working on meristem culture from adult trees.

AGRONOMY AND PLANT NUTRITION

Chairman : **E. V. NELLIAT**

Rapporteur : **K. SHAMA BHAT**

Effect of Rainfall, Age and Position on the Nutrient Content of Cashewnut Leaf on Tin Tailing in Malaysia

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Abstract

The effect of rainfall, age and position of the leaf on the nutrient contents of cashew (*Anacardium occidentale* L.) planted on tin tailing was studied for one year (1976). The young leaves showed significantly higher N, P and K contents than older leaves. During dry months, the N and K contents were higher in young leaves than during wet months, indicating the mobility of these nutrients in leaves. Leaves sampled at the growing terminal had significantly higher nutrient contents than those at the basal parts of the branch. The agronomic significance in relation to the manuring programme of cashew on sandy tin tailing under the agro-environment in Malayasia is discussed.

Introduction

In Peninsular Malaysia, cashewnut is confined mainly to sandy soils in the Langkawi Islands of the west coast and on the 'bris' soils of the east coast. Apart from the work of Osman (1972) on its cultivation on the 'bris' soils the general agronomy and nutrition of the crop is relatively unknown in Malaysia. As the crop is mainly confined to the light textured soils, the water and nutrient contents must have some effect on its leaf nutrient status. Further the age and position of leaf may influence the nutrient status of cashew as observed in other fruit crops (McClung and Lott, 1956; Chadha et al. 1973). Assuming that the nutrient concentration in leaf may be indicative of the nutritional status of the plant, the present investigation was undertaken to understand the effect of moisture, age and leaf position on the nutrient status of cashew. The study was carried out on tin tailing site at the University of Agriculture Farm, Serdang, located 25 km South of Kuala Lumpur.

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Materials and Methods

The experiment was carried out on six year old cashew trees planted at 20 m x 10 m giving a density of 100 plants/ha. The tin tailing (mining waste land) soils at the University Farm can be rated as sandy (96.4% sand) with caly and silt contents being 1.60 per cent and 2.04 per cent respectively.

Fertilizers were applied twice a year during the months of March and September, using CCM 40 (12:6:22:3) and NPK Blue Special (12:12:17:2 +T.E.). The rate of application was 450 g per tree per application, and fertilizers were placed in trenches, 2-3 m from the base of the trunk extending slightly further than its canopy (Tsakiris and Northwood, 1967).

Leaf Sampling : Leaf samples were collected in a completely randomised design. Fourteen normal cashew trees were randomly selected so as to cover the entire area (Fig. 1). Standardization of the selected trees was done with the aid of T-shape aluminium rod also used with other fruit trees (Othman Yaacob, Mohammed Noor Ismail and Awaluddin, 1978).

Monthly sampling of leaves was done from marked branches of the selected tree from north, south, east and western sides. Sampling was done on both fruiting and non-fruiting branches. Each sample consisted six young and six mature leaves giving a total of 24 leaves of each type from four portions of the tree. Sampling was done between 8.00 and 10.30 a.m. (Chapman, 1964).

The leaves were dried for 24 hours in a forced draft oven set at 65 °C. The dried sample was ground in a Wiley mill to pass through a 20 mesh sieve.

Plant nitrogen, phosphorus and potassium were determined from a single plant digestion on a Technicon II Auto-analyser following the method described by Thomas, Sheard and Moyer (1967).

Results and Discussion

Rainfall pattern and leaf age : The range and deviation (%) of nutrient levels observed in young and mature leaves of cashew on tin tailing in Malaysia during the study are presented in Table. 1. A large deviation was found in the N content particularly in the young leaves when compared with P or K. In young leaf the N content was high when the rainfall for the period (July) is low, reflecting the increased mobility of N in younger leaves than in old leaves (Fig. 2). The variation in rainfall however, did not affect the P and K status as that of N irrespective of the age of the leaf and season.

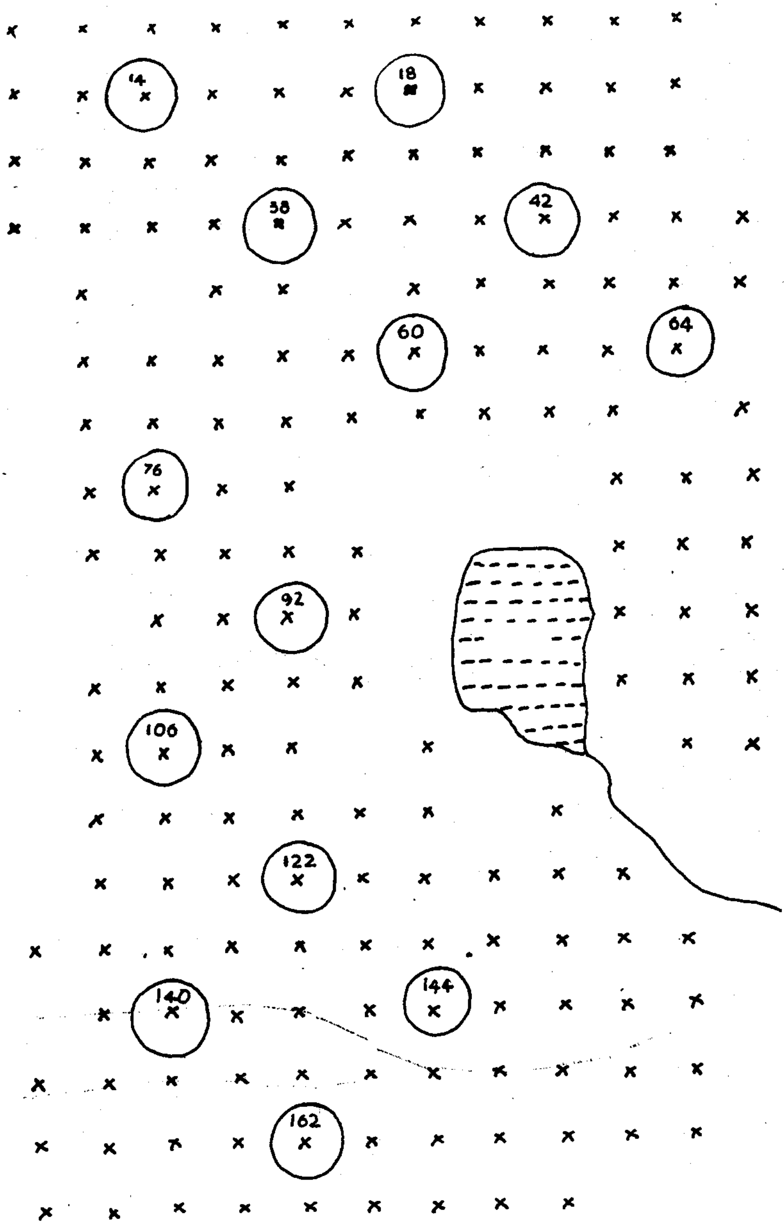

Fig. 1. Plan of cashew orchard on tin tailing in Malaysia.

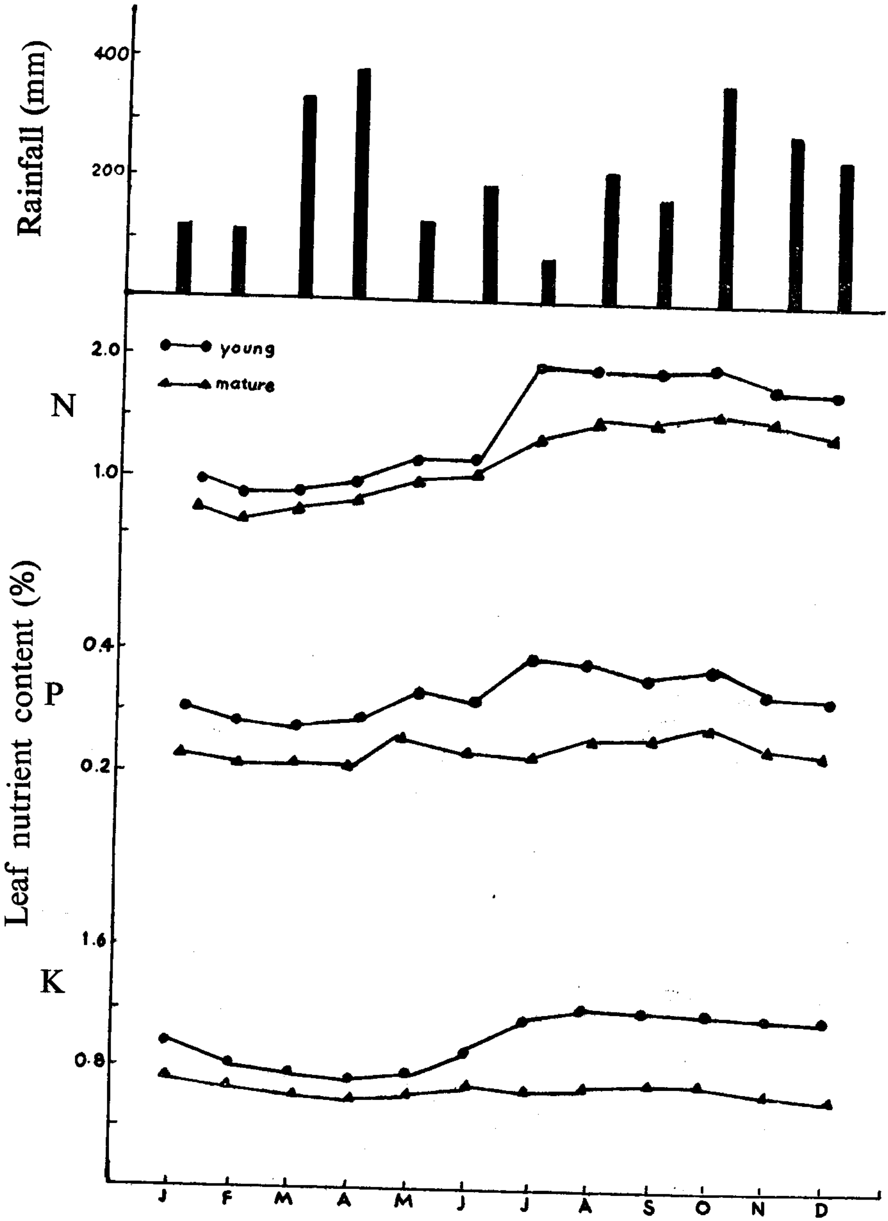

Fig. 2 Monthly rainfall (mm) and changes in the nutrients of young and mature cashew leaves on tin taining in Malaysia.

TABLE 1. **Range and Deviation of Nutrient Content in Young (Y) and Mature (M) Cashew Leaves on Tin Tailing in Malaysia**

Nutrient %	*Leaf age*	*Highest*	*Lowest*	*Average*	*% Deviation*
N	Y	1.99	0.89	1.44	124
	M	1.55	1.05	1.32	51
P	Y	0.40	0.32	0.36	25
	M	0.31	0.23	0.27	35
K	Y	1.23	0.92	1.08	34
	M	0.77	0.65	0.71	18

Rainfall pattern and leaf position: In general, the N and K in young leaves were significantly ($P>0.05$) higher than that of the mature leaves as also observed in other fruit crops (McClung and Lott, 1956). During the dry months (June-August), the N, P and K contents of young leaf was relatively higher than during wet months, although fertilizers were applied in March and September (Fig. 2). It appears that the mobile nutrients (N and K) are affected by the rainfall pattern. Moreover, N and K may be lost through leaching from the sandy soil medium leaving little for plant uptake, as indicated by low N and K contents during the wet months. However, these effects are not clear-cut in the present study, probably due to the well adopted nautre of cashew to dry areas and its greater root spread (Tsakiris and Northwood, 1967).

TABLE 2. **Effect of Leaf Position on the Nutrient Content of Cashew on Tin Tailing in Malaysia**

Nutrient	*Leaf position*	
	Terminal	*Basel*
N	1.89^{a}	1.32^{b}
P	1.39^{p}	0.23^{q}
K	1.14^{x}	0.71^{y}

Values with same lower case letters in each row are not significantly different at $P>0.05$.

There was a significant difference between the nutrient content of leaves at different positions on the branch (Table 2). Leaves taken at the growing point had significantly ($P > 0.05$) higher N, P and K than that sampled at basel point of the branch indicating the concentration of these elements at the growing point. Similar observations were also made by Batjer and Westwood (1958).

From these results, it appears that fertilizer application to cashew on sandy soils including tin tailings needs to be modified. In addition to commercial fertilizers, organic manures and other slow-release fertilizers may be desirable to reduce leaching losses. For trees at bearing stage foliar application together with appropriate insecticide-fungicide mixture may also be desirable.

Acknowledgement

We would like to thank all field and laboratory staff who had helped us in this project which formed part of the programme on "Fruit Research" and "Reclamation of Tin Tailing". The financial assistance was provided by the University of Agriculture, Malaysia, to enable us to present this paper.

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The Effect of Liming and Phosphorus Application on the Leaf Nutrient Contents of Cashew on Tin Tailing and Bris soils in Malaysia

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Abstract

Liming increases the pH of bris soils much more than tin tailing soils eventhough both are sandy in texture. Increasing the amount of lime increases the N, P and K content of the young cashew leaves but not that of mature leaves. In bris soils response to lime and phosphate fertilizer application was better. Application of lime and phosphorus both together increased the N, P and K content of the young leaves on both these light textured soils in Malaysia.

Introduction

The 'tin industry' contributes substantially to the economic progress of Malaysia, but leaving behind desolate large tract of wasteland, locally known as 'tin tailings'. The tailings are the remenents of alluvial mining operations, resulting in the creation of many mining pools, sand tailings, which consists of coarse sand and slime-waste of mainly silt and clay particles (Maene, Mok and Lim, 1973). Both these tailings are planted with vegetables and fruit tree crops. The bris soils, on the other hand, are marine sand deposits varying in width between 180 m to 3 km and form an almost continuous belt along the east coast of Peninsular Malaysia. This strip of land is presently used for tobacco, coconut and cashew. The agricultural potential of both soils have always been low and designated as problem soils. Possibility of ameliorating these soil types through application of lime and phosphorus is studied and results are presented in this paper.

Materials and Methods

This study was started in early January 1978. The experiments were conducted at two different locations, tin tailing soils at the Agricultural University farm and bris soils at a farmers' land in Dungun in east coast of Peninsular Malaysia.

Alternate cashew plants in the row were selected for study. Four levels of lime equivalent to 0, 2.5, 5 and 7.5 tons per hectare and four levels of phosphate viz. P0, P1, P2, P3 equivalent to 0, 35, 70 and 105 kg $P_2 0_5$ per hectare were applied using ground dolamitic limestone and rock phosphate, respectively. In addition, an uniform dose of 250 g of nitrogen, 150 g of potassium, per tree were also applied. These fertilizer mixtures were applied in trenches 15 cm wide and 15 cm deep along the canopy of the plants.

Soil samples were taken at the end of calendar month. The pH of the soils was determined in a soil water ratio of 1:2.5.

Monthly sampling of leaves was made from marked branches at north, south, east and west of the selected trees. Samples were taken from both flowering and non-flowering branches. Twelve young and 12 mature leaves were collected per tree. Leaf sampling was restricted to 8.00 – 10.30 a.m. (Chapman, 1964).

The leaves were dried for 48 hours in a forced draft oven at 65°C. The dried samples were powdered in a Wiley mill to pass through a 20 mesh sieve.

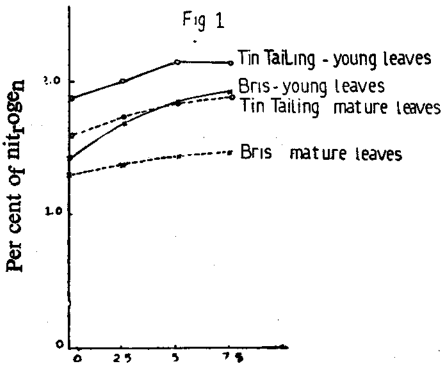
Nitrogen, phosphorus and potassium in the plant material were determined from a single digestion on a Technicon II Auto-Analyser as suggested by Thomas, Sheard and Moyer (1967).

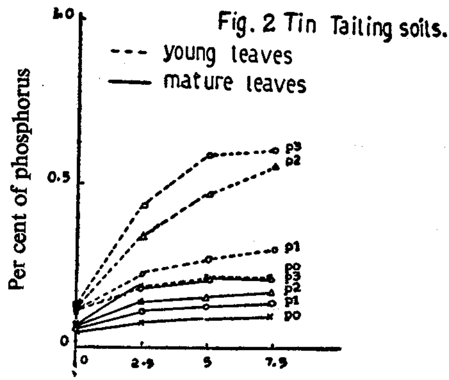
Results and Discussion

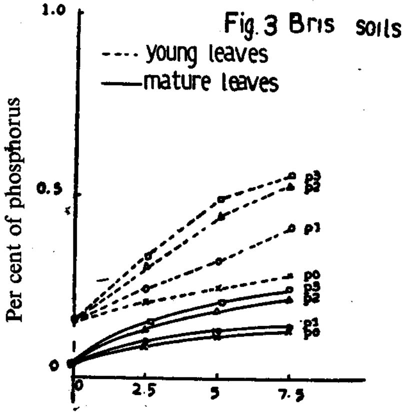
The effect of lime on the pH of soils : There was an increase in the pH of both soils with the application of lime. After six months period the response of tin tailings soils was less than the bris soils. This may be due to slight buffering provided by the presence of clay in the tin tailing soils.

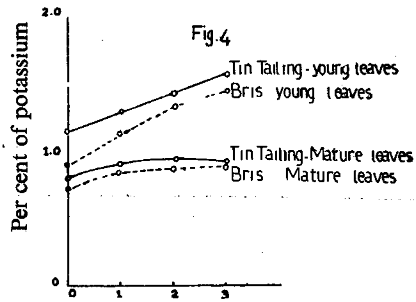
Analytical data of soils : At the beginning of the experiment tin tailing soils were comparatively richer in nutrient status than the bris soils even though both can be rated as poor in nutritional status (Table 1).

Nutrient content of leaves : For both soils the N, P and K contents of the young cashew leaves were higher than the mature leaves (Fig.1). The application of fertilizer increased the accumulation of N in the leaves. This is in agreement to that of Lefebvre (1970) who found that cashew responded to combination of nitrogen and phosphorus, even at low doses. Only marginal difference was noticed in the phosphorus level in both young and mature leaves. The application of fertilizer P increased the P content of the young leaves but very little increase was noticed in the mature leaves. The application of lime further increased the P content in the young leaves of cashew on bris soils more than those growing on the Tin Tailing soils.









Tons of lime added per hectare

Tons of lime added per hectare

This is probably due to the initial P status of bris soils and the improved over all growth pattern of the plants (Fig. 2 and 3). While five tons of lime per hactare was adequate for enhanced availability of P in tin tailing soils a linear relationship was observed between leaf P contents and lime application in bris soil.

In the case of potassium the application of fertilizers increased the K content of young leaves of cashew on the tin tailing more than the bris soils. Lime application does improve the K content of young leaves but had very little effect on the mature leaves (Fig. 4). Jones and Parker (1949) reported that while the level of potassium in orange leaves increased with the application of potassium to the soils no marked influence was noticed when phosphorus was added together with potassium. They found that this is due to the effect of calcium contained in the phosphatic fertilizers.

TABLE 1. **Analytical Data of Tin Tailing and Bris soils in Malaysia**

Sl. No.	*Particulars of anulysis*		*Soil type*	
			Tin Tailing	*Bris*
1.	Clay	%	1.60	0.00
2.	Silt	%	2.04	0.00
3.	Fine sand	%	24.90	54.00
4.	Coarse sand	%	71.46	46.00
5.	Total N	%	0.02	0.01
6.	P	ppm	14.00	2.00
7.	K	ppm	20.00	5.00
8.	C E C	me/100 g	3–4	1–2.5
9.	pH	..	4.60	4.20

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Effect of Nitrogen, Phosphorus and Potash Fertilization on Growth and Production of Cashewnut

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Abstract

The results of a fertilizer trial conducted since 1969 at the Regional Cashewnut Research Station, Vengurla (Maharashtra), have shown that while nitrogen and phosphorus increased the tree volume and yield of nuts significantly, no response was observed to potash fertilization. Response to nitrogen 125 kg/ha in presence of phosphorus (50 kg/ha) and potash (100 kg/ha) was observed. However, the response to nitrogen was restricted to 75 kg/ha in the absence of phosphorus and potash. Similarly the response to phosphorus was restricted to 25 kg/ha when lower levels of nitrogen (25 kg or 75 kg/ha) were applied. Response to phosphorus increased when nitrogen level was also increased to its maximum and the N x P interaction was significant. The main effects of nitrogen and phosphorus and their interaction on tree volume and yield were significant. However, their response at higher levels were controlled by potash application.

Introduction

The areas brought under cashew are mostly infertile waste lands of littoral sand, red sandy loams and laterite soils. Mohapatra, Kumar and Bhat (1973) have reported the annual nutrient removal by a mature cahsew tree as 2.84 kg N, 0.75 kg P_2O_5 and 1.27 kg. K_2O. This amount of nutrients are needed for one year growth of various plant parts. Recent experimental evidence indicated that cashew responded to application of farm yard manure and NPK fertilizer mixtures in balanced doses. The results of the experiments on the requirement of N, P and K for cashewnut are presented in this paper.

Materials and Methods

An experiment was laid out at the Regional Cashewnut Research Station, Vengurla during 1969 in 3^3 confounded design with two replications using seedling progenies of a single mother plant (Sawantwadi), planted at 7.2 x 7.2 m. There were 27 treatment combinations with three levels each of nitrogen (25, 75, 125 kg N/ha), phosphate (0, 25, 50 kg P_2O_5/ha) and potash (0, 50, 100 kg K_2O/ha). The experimental site lies on the west coast at 15.72 N latitude and 72.38 E longitude and 8 m above MSL. The climate is tropical with high humidity and warm weather throughout the year. The temperatures are equable with an average annual rainfall of 2770 mm distributed mainly during June to September. The soil is laterite and acidic having a pH range of 4.5 to 5.3.

Nitrogen was applied in two splits, the first half dose in July and the second half dose in August along with full doses of phosphate and potash. The source of N, P and K were ammonium sulphate, rock phosphate and muriate of potash respectively. The treatments were imposed from second year of the planting. Regular plant protection measures were adopted. The growth observations on volume attained by the trees were recorded in June 1978, and the yield of nuts during 1977–78 season.

Results and Discussion

The data on the volume of tree under different treatments are presented in Table 1. Nitrogen application had significant effect on the voulme of trees. Maximum volume was recorded in 125 kg/ha. Higher levels i.e. 75 kg and 125 kg N/ha were at par but significantly increased the volume of trees over lower level of nitrogen i.e. 25 kg N/ha. Similarly phosphate application was highly significant in increasing the volume of trees. Both levels i.e., 25 kg and 50 kg P_2O_5/ha were at par but significantly superior over control in increasing the volume. Potash application did not produce significant difference in volume of trees.

The interactions between nitrogen and phosphate, nitrogen and potash, phosphate and potash were found to be significant. The combined effect of 125 kg N + 50 kg P_2O_5/ha resulted in maximum volume. The results, are in confirmity with the work of Lefebvre (1973).

Nitrogen fertilization significantly influenced the yield of nuts (Table 2). Highest yield (380 kg/ha) was obtained in treatment receiving 125 kg N/ha. However 75 kg N and 125 kg N/ha were at par and significantly superior over 25 kg N/ha. Earlier reports indicated that the nitrogen application @ 500 g and 600 g per tree at two different locations had significantly increased the yield of nuts (AICS/CIP, 1978).

The yield at 25 kg and 50 kg P_2O_5/ha phosphate application was significantly superior over control. Application of 50 Kg P_2O_5/ha has given the highest yield of 455.67 kg nuts and was significantly superior over 25 kg P_2O_5/ha.

TABLE 1. **Effect of N, P and K Fertilizers on Volume of Trees (m^3)**

(kg/ha)		*N1* 25	*N2* 75	*N3* 125	*Mean*	*P0* 0	*P1* 25	*P2* 50
0	K0	133.29	214.19	214.75	187.14	81.14	208.24	272.85
50	K1	113.20	258.52	263.86	211.86	155.11	243.75	236.72
100	K2	141.57	188.08	240.22	189.96	109.55	223.12	237.20
Mean		129.55	220.26	239.61		115.27	225.04	248.92
	P0	74.54	152.85	118.41	S.E. for NPK		..	9.52
	P1	138.68	263.96	272.47	C.D. at 5%		..	27.41
	P2	174.84	243.98	327.94	S.E. for NP, NK & PK.			16.48
					C.D. at 5%		..	47.45

TABLE 2. **Effect of N, P and K Fertilization on Yield (kg) of Nuts/ha**

kg/ha		*N1* 25	*N2* 75	*N3* 125	*Mean*	*P0* 0	*P1* 25	*P2* 50
0	K0	153.10	127.33	126.31	135.58	87.50	97.38	221.86
50	K1	387.98	354.00	272.30	338.09	119.51	515.85	378.92
100	K2	309.67	406.47	425.69	380.61	73.09	302.51	766.23
Mean		283.58	295.93	274.77		93.36	305.25	455.67
	P0	52.82	128.16	99.12	S.E. for N, P and K		..	32.26
	P1	283.44	374.14	258.17	C.D. at 5%		..	107.60
	P2	514.49	385.51	467.01	S.E. for NP, NK & PK		..	64.54
Mean		283.59	295.93	274.43	C.D. at 5%		..	186.36

Potash application did not show significant difference in the yield of nuts. Lefebvre (1973) also opined that K was relatively unimportant in cashewnut nutrition.

Combined application of nitrogen and phosphate have significantly increased the yield of nuts. The highest yield (766 kg) was recorded with a combination of 125 kg N + 50 kg P_2O_5/ha. In general, there was response to nitrogen upto 125 kg N/ha when phosphate and potash was also applied. In the absence of phosphate and potash response to nitrogen was restricted to 75 kg N/ha. Similarly, response to phosphate was only upto 25 kg P_2O_5/ha at lower level of nitrogen but response was enhanced significantly as the nitrogen level increased to its maximum.

It could be concluded from the results that the response to nitrogen and phosphorus at higher level are controlled by the potash application. Hence, proper balance of all the three nutrients is essential for obtaining good growth and yields of cashewnut.

Acknowledgement

The authors are grateful to Dr. P.V. Salvi, Vice-Chancellor, Konkan Krishi Vidyapeeth, Dapoli and to Dr. M.C. Nambiar, Project Co-ordinator Spices & Cashewnut for encouragement and providing the necessary facilities during the course of investigation.

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ENTOMOLOGY AND PLANT PATHOLOGY

Chairman : **M. R. G. K. NAIR**

Rapporteur : **K. K. N. NAMBIAR**

Seasonal Abundance of Tea Mosquito (*Helopeltis antonii* Sign.) on Cashew in Relation to Meteorological Factors

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Abstract

Seasonal fluctuations in the population density of tea mosquito, *Helopeltis antonii* Signoret, were studied during June 1972 to May 1977 at weekly intervals. The build up of pest population commenced in October – November synchronising with the emergence of new flushes in cashew after the cessation of monsoon showers. The pest population reached its peak in January. Tea mosquito was active in the field in different degrees of intensity till May. The population build up of the pest was found to be negatively correlated with the meteorological factors like minimum temperature, minimum relative humidity and rainfall and positively with sunshine. The most favourable period for the rapid multiplication and population build up of the pest was between December to February. During the monsoon season, tea mosquito population was totally absent.

Introduction

Infestation by tea mosquito, *Helopeltis antonii* Signoret, is considered to be one of the major factors limiting cashew production in India. Adults and immature stages of this tiny bug suck sap from the tender shoots, freshly emerged leaves, floral branches, developing nuts and apples. The tissues around the point of entry of the suctorial stylets of this insect become necrotised and develop characteristic lesions presumably due to the action of phytotoxin present in its saliva, injected into the plant tissues at the time of feeding; the adjoining lesions coalesce and finally the affected plant parts dry up. Abraham (1958) estimated the average damage to be 25 per cent in tender shoots and 15 per cent in tender nuts. The infestation of inflorescences results in 'blossom blight' and causes yield losses exceeding 30 per cent (Pillai and Abraham, 1975; Pillai, Dubey and Vijay Singh, 1976). The

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immature nuts infested by this pest develop characteristic eruptive spots and finally shrivel and fall off.

A thorough knowledge of the trends in population build up and seasonal abundance of the pest has become quite essential for evolving effective control schedules against this major pest of cashew. With this objective, the results of population studies of tea mosquito in relation to meteorological factors, from June 1972 to May 1977 are presented in this paper.

Materials and Methods

Seven cashew trees of age group 15 to 20 years were selected at random, from a total of 140 trees available in the C.P.C.R.I. Farm at Kasaragod, Kerala. Five to eight unit areas, each of 50 cm^2, were selected and tagged with metal labels in each of the seven experimental trees. The number of unit areas per tree was fixed taking into consideration the canopy growth of a particular sample tree. Observations on the total number of shoots, number of tea mosquito infested shoots, total number of panicles, pest infested panicles and the counts on pest population (adults and nymphs) present in each of the unit areas were recorded between 8.00 and 9.30 a.m. at weekly intervals. Observations were recorded with the least disturbance to the shoots/panicles in order to ensure that the adult bugs present on the tree do not fly away and the immature stages do not migrate to the interior of the canopy. The meteorological data such as maximum and minimum temperature, relative humidity, rainfall and the total hours of bright sunshine were also recorded daily. This study was continued upto the end of May 1977 and the results obtained during the five year period of study are discussed.

Results and Discussion

The monthly average population of tea mosquito and the intensity of percentage infestation on shoots and panicles are presented in Table 1. The trends in population build up and the abundance of the pest showed a slight variation between years. In 1972–73 and 1973–74, the build up of the pest population commenced in October itself, whereas in subsequent years it commenced only in November. This could be attributed to the extended monsoon period. The tea mosquito population build up starts synchronising with the emergence of new flushes in cashew and reached its peak in January (except in 1975–76 when the pest population from a low level in Novemebr reached to a peak in February only), three months after the commencement of population build up particularly when the trees were in full blossom. The pest was active in the field in varying intensities till May, as succulent plant parts such as tender shoots, inflorescences, immature nuts and apples in various stages of developement were quite abundant,

TABLE 1. **Population of Adults and Nymphs of *Helopeltis antonii* and Percentage Infestation on Tender Shoots and Inflorescences (1972 - 73 to 1976 - 77).**

Month	*Pest population*		*% infestation*			
			Tender shoots		*Inflorescences*	
	Range	*Mean*	*Range*	*Mean*	*Range*	*Mean*
June	..	..	0.0–53.5	20.66	..	..
July	..	..	0.0–23.8	6.90	..	..
August	..	..	..	..	..	..
September	..	..	..	..	..	..
October	0 – 7	1.60	0.0 – 1.1	0.23	0.0 – 40.6	8.10
November	4 – 41	17.20	0.0 – 23.1	7.24	0.0 – 60.5	19.30
December	13 – 43	27.00	0.4 – 26.6	15.65	0.0 – 61.0	20.00
January	18 – 63	40.60	0.7 – 39.5	13.75	4.7 – 35.7	23.10
February	10 – 67	33.20	0.2 – 36.5	12.38	7.1 – 34.3	18.00
March	5 – 52	21.40	0.4 – 45.2	16.56	6.2 – 36.2	15.60
April	1 – 13	6.80	0. 5– 19.5	9.50	6.3 – 37.5	15.40
May	0 – 6	2.00	0.4 – 19.9	8.48	5.7 – 36.5	13.90

offering ideal sources of food and sites for egg laying and multiplication of pest. Pest population declined from May onwards and it was totally absent during June to September, the south west monsoon season.

The pest population and the monthly counts on intensity of infestation on panicles followed more or less the same trend in all years, the percentage infestation being less than the number of the pests present. When the mean numbers of the pest were 27, 41 and 33 in December, January and February the mean percentages of the inflorescence infestation were 20, 23 and 18 respectively. The mean percentage of shoot infestation also showed nearly the same trend. Eventhough the pest population was totally absent from June to September a mean percentage of 20.66 and 6.90 shoot infestation was recorded during June and July respectively. It is quite possible that infestations in the prior period by the lingering tea mosquito population on the post-harvest flushes might have been available on trees during this period as well.

TABLE 2. **Meteorological Parametres during the Five Year Period of the Study (1972 - 73 to 1976 - 77)**

Month	*Minimum temperature °C.*	*R.H. %*	*Rainfall (mm)*	*Bright sunshine hrs.*
June	23.4*	76.6	784.7	4.8
July	22.9	84.6	832.0	3.0
August	22.7	82.0	626.2	3.7
September	22.9	78.3	297.0	6.0
October	23.1	72.6	176.8	6.5
November	21.7	62.6	76.8	7.9
December	20.2	49.3	140.9	9.0
January	19.4	51.6	..	9.5
February	21.3	59.0	..	9.8
March	23.2	62.0	13.2	9.6
April	25.1	61.6	102.1	9.2
May	24.2	70.6	383.5	7.3

TABLE 3. **Correlation of Meteorological Parameters with Tea Mosquito Infestation**

	Inflorescence infestation	*Pest population*	*Minimum Temperature*	*Minimum RH*	*Rainfall*	*Sunshine*
Shoot infestation	0.414	0.504	−0.231	−0.532	0.116	0.437
Inflorescence infestation	..	0.835**	−0.479	−0.942**	−0.842**	0.907**
Pest population	..	..	−0.782**	−0.875**	−0.719**	0.783**
Minimum Temperature	..	..	..	0.566	0.352	0.314
Minimum RH	..	..	..	..	0.820**	−0.917**
Rainfall	..	..	..	..	..	−0.927**

The monthly variations in the average values of meteorological factors such as temperature, relative humidity, rainfall and hours of sunshine for the entire period of study (Table 2) were correlated with fluctuations in population density of the pest (Table 3). As seen from the data, the population build up of the pest was found to be negatively correlated with factors like minimum temperature, minimum relative humidity and rainfall and positively with sunshine.

There was no pest population from June to September, when relative humidity and rainfall were quite high and the period of bright sunshine was very low. The build up of pest population from a very low level (1.6%) commenced in October and reached its peak (40.6%) in January, when the minimum temperature was very low (19.4 °C), minimum relative humidity also was rather low (51.6%), rainfall nil and the duration of bright sunshine was quite high (9.5 hrs). The data also revealed that the most favourable period for rapid muliplication and population build up of tea mosquito was December, January and February, when the mean duration of bright sunshine ranged from 9.02 to 9.8 hrs. Eventhough tea mosquito is known to be an insect which normally shuns bright sunlight, it was observed to continue its destructive activity hiding on the ventral surface of leaves and feeding on the midrib, petiole, tender shoot or panicle. Moreover, it is during this period the host plant also provided an abundant supply of succulent plant parts. However, during the monsoon period, June to September, the relative humidity (76.6 – 82.0%) and rainfall (297 – 832 mm) were quite high, the duration of bright sunshine was too meagre (3 – 6 hrs) and the succulent plant parts were not normally available on grown up trees, and as such, the tea mosquito population also was totally absent.

Swaine (1959) also observed the absence of *Helopeltis anacardii* Miller during the rainy season and its abundance during the flushing season (July-November) after the monsoon in Tanganyika territory. He reported that the insects were scarce on older trees from December until June, but they were readily found on young trees in December–April as these were putting on a considerable amount of new and succulent growth during this period in addition to the main growth after June.

Another important observtion made from the present study was that the population density of tea mosquito and the intensity of its incidence varied from tree to tree, some trees being heavily infested, others less so, and some others remaining practically free from pest infestation. Some what similar observations have been reported by Fennah (1963) in the case of the red banded cacao thrips, *Selenothrips rubrocinctus* (Giard) infesting cashew trees also in Trinidad, West Indies.

The mechanism which governs the relationship between the host plant and the insects infesting it under varying agro-ecological situations invites further detailed investigations.

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Discussion

R. Russell: You have established the incidence of *Helopeltis* on cashew during certain months of a year. There are times when no *Helopeltis* was found. Where did they go?

G.B. Pillai: *Helopeltis antonii* has a good number of alternate host plants. Guava, cacao, neem, mahogany, cinchona, red gum, apple, grapes, etc. are the more important ones. Moreover, the population of *H. antonii* will be available on young cashew trees/seedlings which will have succulent flushes almost throughout the year.

C.C. Abraham: Did you work out the correlation between mean maximum temperatures and population fluctuations of *Helopeltis?* It is reported that the population build up is positively correlated with sunshine. This may please be explained in the light of the general habit of *Helopeltis* to prefer shady situations inside the canopy during day times.

G.B. Pillai: (1) There was no significant correlation between maximum temperature and pest population. (2) Significant positive correlation between the duration of bright sunshine and population build up of tea mosquito was recorded. Tea mosquito feeds by remaining in shady positions.

A.G. Ibrahim: Do you have any data to show the preference of the mirid to different clones of cashew. Did you consider the populations of the natural enemies i.e. parasites/predators in your trials?

G.B. Pillai: Some studies on the incidence of tea mosquito on different accessions of cashew germplasm assemblage at Vittal are being made. (2) We have not come across any parasitoid of this pest so far of. However, predators like a species of hunter spider and the red ant (*Oecophylla samaragdina*) have been observed feeding on the immature stages of the mosquito.

K.K. Vidyadharan: You have mentioned variation between trees on the incidence of tea mosquito attack. Can this low incidence be associated with any specific leaf character.

G.B. Pillai: This needs further study.

T.K. Lim: Has any work been done in India to extract toxin from *Helopeltis* and inoculate on inflorescence instead of using the insects.

G.B. Pillai: We have already initiated this work at C. P. C. R. I. to use it as a tool in the screening of cashew germplasm.

Effect of Topical Application of Juvenile Hormone (JH) Analogues on the Development and Survival of the Cashew Mirid Bug *Helopeltis antonii* Sign.

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Abstract

A laboratory study on the effect of topical application of graded doses of JH analogues, Farnesyl Methyl Ether (FME), ZR 512, and MV 678 on the development and survival of *H. antonii* was conducted. Among the three analogues, FME moulted to sixth instar supernumerary nymphs, whereas the nymphs treated with ZR 512 and MV 678 at 1 μg and 1.5 μg moulted to sixth instar nymphs and adultoids. These post-moulted individuals had comparatively shorter life span than the normal individuals. The nymphs of *H. antonii* treated with the JH analogues showed varying degrees of developmental complexities.

Introduction

Considerable attention has been focussed in recent years on juvenile hormone analogues on account of their insecticidal properties. The JH activity of a large number of compounds has been tested by Wigglesworth (1969) on *Rhodnius prolixus*. Roller and Dahm (1968) and Slama, Romanuk and Sorm (1972) have studied the JH activity on some other species of insects. Hormone analogues induce precocious metamorphosis and sterilization of so many insects. Wigglesworth (1957) reported that JH suppresses the maturation of adults. However, this type of work has not so far been carried out on *Helopeltis antonii* Sign., a major pest of cashew. The present studies were therefore taken up to ascertain the effect of JH analogues on the development and survival of this particular pest.

Materials and Methods

Stock cultures of the test insects were reared out from the adults collected from the field. The early fifth instar nymphs were used for the studies. The stock cultures were maintained at 28 $\pm$ 1 °C. Hormone analogues

ZR 512 and MV 678 were supplied by Chief Scientific Officer, V. C. Farm, Mandyal and Farnesyl Methyl Ether (FME) was obtained from M/s. Eco-control Inc., Cambridge, Mass., U.S.A. The analogues were dissolved in acetone in such a way that 1 μl of the solution contained 1 μg of JH analogue. The analogues were applied topically in single doses of 0.5, 1 and 1.5 μg per nymph on the middle of the dorsum of the third abdominal segment using a micro-syringe. Acetone treated nymphs served as control. Twenty, fifth-instar nymphs were used for each treatment. The treated nymphs were exposed to electric fan air for 15 minutes for drying of the analogue films.

The treated experimental and control insects were then confined on the shoots of potted cashew seedlings of 6 – 8 months growth inside perforated polybags and kept at 25 $\pm$ 1 °C in an insectary. Mortality and other developmental changes were observed daily.

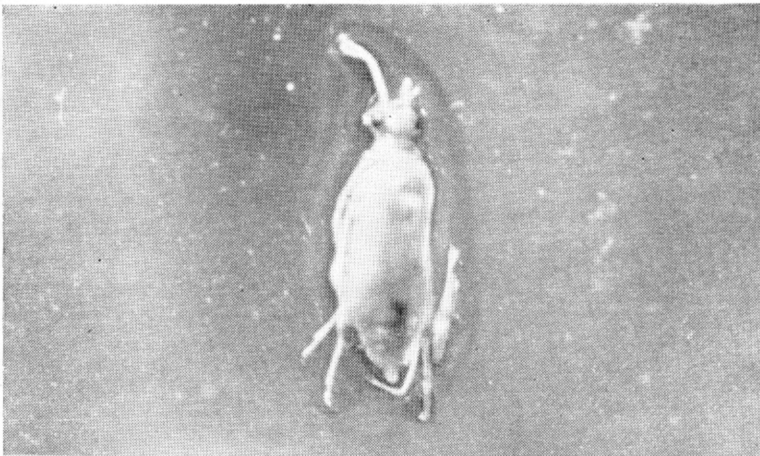
Results and Discussion

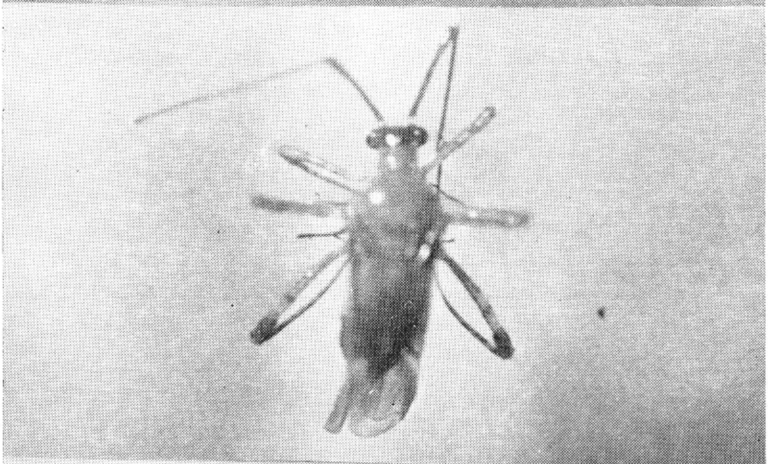
Among the three JH analogues, FME was found to be more effective. The observations on the effect of the three JH analogues at graded doses and survival rate are presented in Table 1.

The mortality of nymphs treated with 0.5 μg FME was 80 per cent within 24 hours. Four moulted to sixth instar supernumerary nymphs (Fig. 1). At doses above 0.5 μg FME was lethal to the treated insects and none completed the fifth instar stage. In the control insects treated with acetone the mortality was only 30 per cent. Controls moulted to normal adults (Fig. 2).

Out of the twenty treated with 0.5 μg of ZR 512, nine died as nymphs within 24 – 30 hours. Five of them moulted as adultoids and six as adults. The application of ZR 512 at the dosage of 1μg per nymph caused high mortality. Twelve out of twenty nymphs treated, died within 24 hours and of the remaining one had normal adult features and seven were adultoids. The treatment of ZR 512 at still higher dosage of 1.5 μg per nymph caused 80 per cent mortality within 24 hours. The surviving four insects emerged as adultoids. The mortality rate in the control was only 25 per cent and the rest moulted as normal adults.

Out of the twenty freshly emerged fifth instar nymphs treated with MV 678 in a single dose of 0.5 μg per nymph, seven died within 24 hours. Among the thirteen emergents, two were adultoids and eleven were adults. The application of MV 678 at the dosage of 1 μg per nymph, caused 55 per cent mortality. Among the post moulted stages, five were adultoids and four were adults. At a higher dosage of 1.5 μg per nymph, MV 678 caused higher mortality of 65 per cent. Out of the moulted seven insects six had adultoid features and only one had adult characters. The controls moulted as normal adults (Fig. 2).





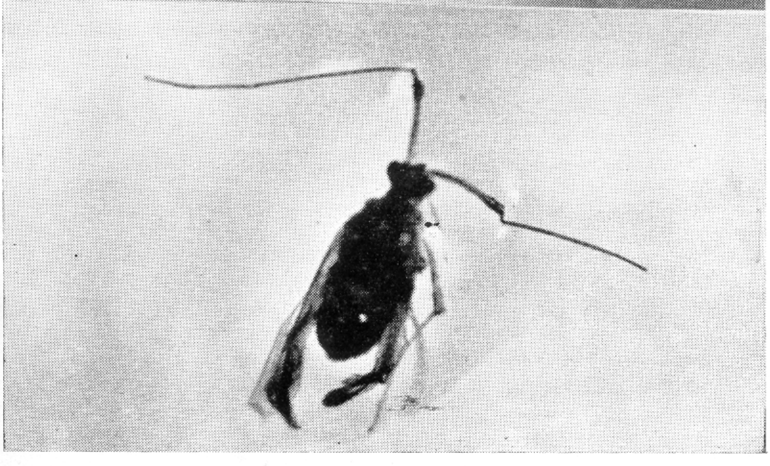


Fig. 1. Fifth instar supernumerary nymph of *H. antonii*

Fig. 2. Normal adult *H. antonii* Fig. 3. Adultoid of *H. antonii*

The moulted sixth instar nymphs were characterized by the presence of wing rudiments, two segmented tarsi and brownish colour of the abdomen. They were quite similar to that of late fifth instar nymphs. The sixth instar nymphs tried for copulation, but they failed. The failure may be due to the imperfect and incomplete developement of the genetalia. Wigglesworth (1957) reported the unique action of the JH, in promoting larval synthesis and in suppressing the maturation of adult.

TABLE 1. **Effect of Topical Application of Three JH Analogues on Early Fifth Instar Nymphs of *H. antonii*.**

Treatment	*Dosage per insect*	*No. of insects treated*	*No. of insects surviving after 24 hrs.,*	*Mortality rate %*	*Nature of post-moult individuals*	*Mean longevity of post-moult individuals*
(1) FME	0.5 μg	20	4	80	Sixth instar supernumerary nymph	2.3
	1 μg	20	0	100	..	..
	1.5 μg	20	0	100	..	..
Control	Acetone	20	14	30	Normal adults	6.6
(2) ZR 512	0.5 μg	20	11	45	5 adultoids and 6 adults	2.6
	1 μg	20	8	60	7 adultoids and 1 adult	2.5
	1.5 μg	20	4	80	4 adultoids	2.6
Control	Acetone	20	15	25	Normal adults	6.4
(3) MV 678	0.5 μg	20	13	35	2 adultoids and 11 adults	2.9
	1 μg	20	9	55	5 adultoids and 4 adults	2.8
	1.5 μg	20	7	65	6 adultoids and 1 adult	2.6
Control	Acetone	20	14	30	Normal adults	6.6

The moulted adultoids (Fig. 3) were also similar to that of the late fifth instars, except for their well developed wings. These adultoids had only two segments in the tarsus. Abdominal cuticle was neither of the fifth instar type nor the adults, but intermediate in its structure. The phenomenon of intermediate characters occurrence was also reported by Wigglesworth (1940), Lawrence, Gilbert and Schneiderman (1960) and Michael Barrett 1974. William (1971) reported that pupae of *Tenebrio* and *Tribolium* moult to pupal -adult intermediates due to hormone treatment. They were of the opinion that hormone should be able to stimulate supernumerary moulting of immature insects. Roller and Dham (1968) had obtained supernumerary moulting from *Tribolium* due to hormone treatment. Prabhu, John and Ambikamma (1973) reported that when FME was applied in single dose 0.1 to 2.0 μg per nymph topically on early fifth instar nymphs of *Dysdercus cingulatus*, they moulted to sixth instar supernumerary nymphs. Gelbic and Sehnal (1973) also obtained the intermediate forms when they applied ceoropia juvenile hormone into last instar larvae of *Cydia pomonella* (L.). In the present studies, all the sixth instar nymphs and adultoids could not live more than 2–3 days, whereas the control insects moulted as normal adults and survived for 6–7 days. The mean longevity of the sixth instar nymphs moulted from the nymphs treated with 0.5 μg FME, was 2.3 days. The mean longevity of the adultoids moulted from the nymphs treated with ZR 512 at the dosages of 0.5, 1 and 1.5 μg was 2.6, 2.5 and 2.6 days respectively. In the case of MV 678, the adultoids moulted from the nymphs treated with the dosages of 0.5, 1 and 1.5 μg, the mean longevity was 2.9, 2.8 and 2.6 days respectively.

Acknowledgement

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Discussion

Chai Tiang Bian: I understand that you have found a predator of tea mosquito nymphs. Have you studied the effectiveness and possibility of using this predator to control the tea mosquito? Have you found any parasites living on tea mosquito?

B. Ambika: The myrmecine ant *Crematogaster wroughtoni* is found to feed on the first and second instar nymphs of *Helopeltis*. These ants are capable of feeding on about 10 nymphs per day. Conservation and augmentation of the ants in plantations appear to the best strategy. Further work on bio-suppression of the pest using the predator is in progress.

G.B. Pillai: Under the temperature range of 23 – 35 °C and 73 – 100 per cent R.H. (in the lab. at Kasaragod) tea mosquito completed its life cycle in 16–17 days. What can be the possible explanation for variation in the duration of life cycle at Vellanikkara conditions?

C.C. Abraham: At Vellanikkara the durations of development of the different stages was studied at constant temperature of 28 $\pm$ 1°C. Under this condition the total duration of life cycle is found to be 22.2 days. The variation can be ascribed to the fluctuating levels of temperature and humidity at Kasaragod.

G. Oblisami: (1) What is the extent of damage caused by sixth instar supernumerary nymphs transformed by FME treatment when compared to the fifth instar nymphs? (2) Whether any study on fourth instar nymphs was made to understand the effect of juvenile hormone analogues?

B. Ambika: (1) Sixth instar supernumerary nymphs do not feed and are inactive. They also cannot reproduce. They live only for 2–3 days. (2) No.

The Foliar Application of Pesticides and Nitrogen on the Incidence of Tea Mosquito Bug (*Helopeltis antonii* Sign.) and Yield of Cashew

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Abstract

A trial was conducted for three years from 1976-78 to study the efficacy of combined spray of urea and endosulfan (0.05%) on the yield of cashew and control of tea mosquito on the ten year old trees of cashew selection M 10/4 at Cashew Research Station, Vridhachalam. Three sprays of endosulfan with urea (3%) gave highest mean yield of nuts uniformly over years compared to control. Three sprays of endosulfan alone or in combination with urea were found effective in controlling the tea mosquito.

Introduction

In cashew the production of new shoots and subsequent initiation of the inflorescence is influenced by nitrogen fertilization. The tea mosquito (*Helopeltis antonii*) which normally attacks the tender shoots of cashew is a major pest causing heavy economic losses to the crop. Therefore it is thought worthwhile to investigate the combined influence of pesticide and a nitrogen source on the yield and productivity of cashew. The quick response to foliar feeding of nitrogen in many of the fruit trees has been well established (Blasberg, 1953; Caim, 1956; Nair, George and Tajuddin, 1972). The possibility of minimising the cost of plant protection and fertilizer application in increasing the productivity of cashew was investigated.

Materials and Methods

A field experiment was conducted at Cashew Research Station, Vridhachalam for three years, on ten year old seedling progenies of the high yielding selection M10/4.

The treatments were:

1. Endosulfan (0.05%) - Two sprays
2. Endosulfan (0.05%) - Three sprays

3. Endosulfan (0.05%) + Urea (3%) – Two sprays

4. Endosulfan (0.05%) + Urea (3%) – Three sprays

5. Unsprayed control

Sprayings were done with high volume sprayer and wherever a mixture of urea and endosulfan was used a pinch of copper sulphate was added to prevent scorching. The plot size was six trees with four replications. In addition to yield, data on the incidence of tea mosquito were recorded by counting the infestation over the panicle, shoot, fruit and nut.

Results and Discussion

The data on the incidence of tea mosquito on the shoot, panicle, fruit and nut are presented in Table 1. The maximum control of tea mosquito bug was recorded in the treatment with three sprays of endosulfan alone and endosulfan mixed with urea. With the reduction in incidence of the tea mosquito on the shoot, the percentage of incidence in the panicles, fruits and nuts was also reduced resulting in enhanced nut yield.

TABLE 1. **Effect of Foliar Application of Pesticides and Urea on the Incidence of Tea Mosquito**

S.No.	*Treatment*	*No. of sprays*	*% infestation*			
			Shoot	*Panicle*	*Fruit*	*Nut*
1.	Endosulfan 0.05%	2	5.82	6.94	3.10	7.20
2.	Endosulfan 0.05%	3	4.63	2.49	2.18	0.82
3.	Endosulfan 0.05% + Urea 3%	2	6.12	5.82	2.90	6.80
4.	Endosulfan 0.05% + Urea 3%	3	3.20	2.87	3.00	1.80
5.	Unsprayed control	–	100.00	100.00	100.00	100.00

In all the three years (1976–78) the plants receiving three sprayings of endosulfan mixed with urea gave highest yield (Table 2). Two sprays with the endosulfan with urea was at par with three sprays in 1976 only while in remaining years three sprays gave higher yield both in terms of weight of nuts as well as number of nuts. The spraying of endosulfan alone either in two or three sprays resulted in significantly lesser yield when compared to endosulfan with urea sprays. However all the four treatments were significantly superior to control.

TABLE 2. **Effect of Foliar Application of Pesticides and Nitrogen on Cashew Yield**

S.No.	Treatment	No. of sprays	Mean yield per tree					
			1976		1977		1978	
			Weight (kg)	No.	Weight (kg)	No.	Weight (kg)	No.
1.	Endosulfan 0.05%	2	1.44	484	1.77	609	3.62	536
2.	Endosulfan 0.05%	3	2.17	702	2.57	864	4.43	785
3.	Endosulfan 0.05% + Urea	2	2.18	737	2.81	943	5.87	825
4.	Endosulfan 0.05% + Urea	3	2.80	922	3.28	111	7.63	127
5.	Control	–	1.02	306	1.34	485	1.82	303
	F Test		**	*	**	*	*	NS
	SED		0.28	92.70	0.14	49.20	0.68	..
	CD		0.61	202.12	0.31	107.03	1.48	..

* Significant at 5% level; **Significant at 1% level; NS – Not Significant

Commercial urea as a source of nitrogen was found to be effective as foliar spray aiding in absorption and reducing the possible leaching lossess through the soil (Nair, George and Tajuddin, 1972; Sarma, Thakur and Chadha, 1977). Endosulfan was found to be effective for controlling the tea mosquito when it was sprayed during shooting, flowering and fruit and nut development stage (Pillai, Dubey and Vijay Singh, 1976). In the present study foliar application of endosulfan with urea reduced the incidence of pest and also enhanced the yeild of cashewnut.

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Aerial Spraying Against Tea Mosquito in Cashew

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Abstract

Comparative efficacy of ultra low volume (aerial spray) and the high volume spray (employing rocker sprayer) for the control of tea mosquito was evaluated during 1977–78 season in the cashew plantations of Kerala Plantation Corporation at Muliyar, Adhur and Perla villages, in Kerala, India. Two sprays were given in November, 1977 and January, 1978 synchronising with the emergence of new flushes and inflorescences. The infestation of shoots and inflorescences was significantly reduced in the plots which received aerial spraying and the yield increase was 40 per cent for the number of nuts and 37 per cent for the weight of nuts harvested over the plots receiving high voulme spray (2.2 kg Vs 1.6 kg per tree).

Introduction

Among the major pests of cashew *Helopeltis antonii* Sign., popularly known as 'tea mosquito' is the most serious pest causing heavy economic losses. Abraham (1958) observed that the yield loss due to this pest exceed 30 per cent. Adults and immature stages of this bug suck sap from the tender shoots, leaves, panicles, developing nuts and apples. As such, timely adoption of suitable plant protection measures with appropriate insecticides will control the pest population. Pillai and Abraham (1975) reported the trends in build up of pest population synchronising with the emergence of new flushes and panicles. Chemical control trials conducted at Kasaragod revealed that endosulfan 0.05 per cent applied as high volume spray or 0.1 per cent as low volume spray at the time emergence of new shoots, panicle and fruit set was effective in controlling tea mosquito population and reducing the crop losses (Pillai, Dubey and Vijay Singh, 1976). To cover extensive areas of cashew plantation within the short critical period during which the build up of the tea mosquito population commences and reaches its peak, aerial spraying seem to be the most suitable. This is specially true for plantations situated in hilly tracts. In this paper an attempt

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has been made to evaluate the comparative efficacy of aerial spraying *vis-a-vis* mechanical spraying using rocker sprayers and to work out the cost benefit ratio of both the plant protection methods.

Materials and Methods

The field experiment was conducted at seven locations in the cashew plantations at Muliyar, Adhur and Perla villages of the Plantation Corporation of Kerala. From each location strips of about ten hectares were marked separately and divided into three portions. One portion was aerially sprayed with endosulfan (1.0%) through helicopter, in the second endosulfan (0.5%) was sprayed using rocker sprayers and third portion was left as unsprayed control. Three clusters of three trees from each portion were selected at random having a border of four rows of trees around. Thus 189 trees were selected for this experiment. Ten leader branches were randomly selected and labelled from each tree. The pre-treatment observations on the total number of laterals, flowering laterals and number of shoots and panicles infested with tea mosquito were recorded from each leader. Two rounds of spray one in the second half of November, 1977, at the time of emergence of new flushes and inflorescences and the second in the third week of January, 1978 were given, when the build up of pest population was noticed. The post treatment observations were recorded after an interval of one month. The yield of nuts was recorded for the complete season from five locations at Muliyar and Adhur. An estimate of cost for the two methods of spraying was worked out.

Results and Discussion

The present experiment has confirmed the efficacy of endosulfan treatment in controlling the tea mosquito infestation of shoots and panicles (Table 1). Among the two different methods of treatment aerial spraying gave significantly superior results. In terms of angular values, the mean infestation was 8.28 and 26.63 for shoots and panicles respectively in plots receiving aerial spray, compared to 14.42 and 36.08 in plots covered by rocker spray, whereas in control plots the figures were as high as 24.85 and 58.58, for infestation in shoots and panicles respectively. For both the characters wide variability was observed between locations.

Compared to control the yield per tree was higher by 80 per cent for number of nuts as well as weight of nuts in plots covered by aerial spraying and by 30 per cent in plots which received high volume spray (Table 2). However, these differences in yield were not statistically significant and this may be attributed to the high degree of heterogenity existing between cashew trees, as evidenced by the high coefficient of variation (around 90%). These

TABLE 1. **Mean Percentage (transformed values) of Infestation of Shoots and Panicles.**

Location		*Shoots*			*Panicles*	
	Aerial spray	*Rocker spray*	*Control*	*Aerial spray*	*Rocker spray*	*Control*
Muliyar (1)	2.31	7.06	11.70	21.55	31.49	58.52
(2)	2.42	6.33	18.13	22.05	28.00	55.93
Adhur (3)	15.09	19.54	42.44	27.18	40.59	59.30
(4)	11.26	32.40	42.76	36.06	45.30	72.58
(5)	1.19	2.31	7.35	27.48	39.31	49.58
Mean*	6.45	13.53	24.48	26.86	36.94	59.18
Perla (6)	13.29	16.79	26.86	28.99	30.43	49.48
(7)	12.42	16.51	24.69	23.07	37.47	64.68
SE/plot		7.74			9.88	
C.V.%		48.80			24.44	
C.D. for locations		7.37			9.41	
C.D. for treatment		4.82			6.16	
Mean	8.28	14.42	24.85	26.63	36.08	58.58

*Mean for the firsit five locations only

TABLE 2. **Mean Yield of Nuts / Tree**

Locations		*No. of nuts*			*Weight of nuts (kg)*	
	Aerial spray	*Rocker spray*	*Control*	*Aerial spray*	*Rocker spray*	*Control*
Muliyar (1)	208.4	181.1	191.2	1.426	1.122	1.190
(2)	415.3	208.3	88.8	2.628	1.347	0.595
Adhur (3)	330.8	402.9	220.2	2.110	2.708	1.522
(4)	413.6	124.8	60.7	2.623	0.917	0.420
(5)	325.7	293.1	362.9	2.213	1.942	2.418
Mean	338.8	242.0	184.8	2.200	1.607	1.229
S.E./Plot		227.27			1.520	
C.V.%		89.06			92.14	

inter-tree variations have affected the observations on shoot and panicles only to a lesser extent because these observations were restricted to few randomly selected leader branches in each tree, whereas for yield observations the whole tree was taken as the unit. Possibly a third round of spraying during March when fruit set is at its peak, would have made the differences in yield more clear.

The actual expenditure incurred by the Plantation Corporation of Kerala for one round of spraying was Rs. 60/ha whereas the cost of spraying by rocker sprayer was Rs. 76/ha (Anon, 1976). At the 1978 rates of Rs. 6.00 per kg for raw nuts the net income from one hectare of cashew garden would be Rs. 1069 for unsprayed plots, compared to Rs. 1244 for rocker sprayed plots and Rs. 1794 for plots covered by aerial spraying (Table 3). The incremental cost benefit ratio worked out to be 1:2.1 for mechanical spraying compared to 1:5.9 for aerial spraying (at the 1984 rates the ratios are 1:1.5 and 1:5.8 for mechanical and aerial spraying respectively (Table 3)).

TABLE 3. **Economics of spraying (one hectare)**

		Control	*Rocker spray*	*Aerial spray*
Pesticides	Value (Rs.)	..	90 (126)	74 (104)
Spraying	Mandays	..	3 (—)	6.6 (—)
	Cost (Rs.)	..	24 (42)	6 (8)
Other Expenses	(Rs.)	..	40 (50)	40 (50)
Total		..	154 (218)	120 (162)
Harvesting charges	50 Ps./kg. (Rs.)	37 (92)	48 (92)	66 (165)
Total Expenses (Rs.)		37 (92)	202 (338)	186 (327)
Yield	*Quantity* (Kg/ha)	184.5	241	330
	Value (Rs.)	1106 (2029)	1446 (2651)	1980 (3630)
Net Income (Rs.)		1069 (1937)	1204 (2313)	1794 (3303)

Figures in paranthesis are 1984 values

In the present study a helicopter could spray about 400 - 500 ha in a day whereas 400 - 500 mandays are required for covering the same area by conventional methods. Economy in the use of water was an added advantage in places where water scarcity exists.

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Pests of Processed Cashew and their Control

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Abstract

Twenty species of beetles, five species of caterpillars and some psocids and mites infest stored cashew kernels. Among these *Cadra cautella* (Wlk.), *Corcyra cephalonica* (St.) (Pyralidae), *Tribolium castaneum* (Herb.) (Tenebrionidae) and *Necrobia rufipes* (De C.) (Cleridae) cause direct damage to the kernels while others contaminate them with their presence and excreta. Strict sanitation of the processing sheds and premises, keeping processed nuts in closed containers, undertaking peeling, grading and packing in quick succession are suggested as measures to control these pest infestations.

Introduction

Processed cashew kernels are susceptible to infestation and damage by storage pests. Over a dozen species of insects and few mites were recorded to infect cashew kernels by Pillai (1956 and 1959) and Muthu and Pillai (1975). The more important ones which cause direct damage to the kernels were the caterpillars of *Cadra cautella, Corcyra cephalonica* and *Tribolium castaneum* and their larvae. Studies were undertaken on the occurrence and ratio of association of the pests at 14 cashew processing factories spread from Cochin in the north to Kilimanoor in the south. Laboratory studies were also made at the College of Agriculture, Vellayani to find out the most effective insecticides which could be used for factory and premises cleanup. Results of these studies are presented below.

Materials and Methods

Raw nuts were examined for insect infestation along with inferior grade kernels and the sieved out bits of kernels at the time of packing. Besides these the floor of the factory sheds, the baskets and bags used for keeping the processed nuts and the cashew peels were also examined at monthly intervals for the presence of insects . The insect species collected were identified. For evaluating the relative toxicity of different isecticides the concerned insects were exposed to the surface of pertri plates sprayed with the insecticides under a spraying tower and dried. Mortality counts were taken at intervals of 24 hours for four days.

Results and Discussion

The different species of insects found in processed kernels and in the sheds and premises are listed in Table 1. Out of these species the larvae of *Cadra cautella* and *Corcyra cephalonica* and the adults and larvae of *Tribolium castaneum* and *Necrobia rufipes* were found to feed directly on the kernels.

TABLE 1. **Insects Found in Association with Processed Cashew**

Insect species	*Family*	*Found infesting*
1	2	3
Beetles		
Tribolium castaneum (Herb.)	Tenebrionidae	RN, IGK, SBPN
Alphotobinus laevigatus (F.)	,,	IGK, BB, FS, CP,
A. piceus (Olivier)	,,	
Mesomorphus villiger (Blanch)	,,	CP
Pachycera buprestoides (F.)	,,	IGK
Crypticus sp.	,,	
Araecerus fasciculatus (De G.)	Anthribidae	IGK
Sitophilus oryzae (Linn.)	Curculionidae	FS
Lasioderma serricorne (F.)	Anobiidae	IGK, FS
Oryzaephilus surinamensis (Linn.)	Cucujidae	IGK, SBPN, BB, FS, CP
Cryptolestes ferrugineus (Steph.)	,,	RN, IGK, FS, BB, CP
C. pusillus fuscus (Lefk.)	,,	
Necrobia rufipes (De G.)	Cleridae	IGK, FS, BB, SBPN, RN
Gibbium psylloides (Czenp.)	Ptinidae	IGK
Tenebroides mauritanicus (L.)	Trogossitidae	IGK
Monanus concinnulus (Wlk.)	Silvanidae	IGK
Ahasverus advena (Waltl.)	,,	SBPN, FS, IGK, BB, CP, FS
Carpophilus mutilatus (Er.)	Nititulidae	RN, SBPN, BB, IGK, CP, FS
C. pilosellus (Mots.)	,,	
Typhaea stercores (L.)	Mycetophagidae	IGK
Coccotrypes carphophagus (Horn.)	Scolytidae	IGK
Caterpillars		
Cadra cautella (Wlk.)	Pyralidae	RN, IGK, SBPN, BB, CP, FS

1	2	3
Corcyra cephalonica (St.)	Pyralidae	SBPN, BB, IGK, FS, CP
Pyralis manihotalis (Guen.)	,,	FS
Steomorpha rutella (Zell.)	Tineidae	BB, IGK
Erechthias zebrina (Butler)	Lyonetidae	FS

RN = Raw Nuts; IGK = Inferior Grade Kernels; SBPN = Sieved out Bits of Packed Nuts; FS = Floor Sweepings; BB = Gunny Bags and Baskets; CP = Cashew Peel.

Raw nuts showed little infestation under storage. Maximum infestation was found in the stored inferior grade kernels. There was an increase in the insect population in this material from May to October, the population reaching a peak of 409 insects per 100 g of the kernels in October (Table 2). The species found on this material were mainly *Tribolium castaneum, Cadra cautella,* and *Corcyra cephalonica.* Large number of eggs of *C. cautella* and *C. cephalonica* were found in the samples of the material collected. The average counts in the samples varied from 17.5 to 30.2 per 500 g in the different months, indicating the possibility of contamination in tin packages.

TABLE 2. **Counts of Total Insects in Nuts at Different Stages and Intervals of Processing**

Month of observation	*Mean number of insects in*		*Sieved bits from packed kernels* (100 *g*)
	Raw nuts (100 *nuts*)	*Inferior grade kernels* (100 *g*)	
May	0	28.8 (3 – 70)	22.0 (9 – 43)
June	.. (0 – 5)	47.5 (3 – 285)	17.5 (7 – 43)
August	10.2 (0 – 26)	98.5 (7 – 497)	29.4 (7 – 55)
September	2.0 (0 – 9)	112.0 (31 – 463)	25.2 (21–31)
October	22.0 (0 – 85)	409.5 (23 – 449)	30.2 (6 – 42)

Insects were abundantly present in all these locales which served as spring boards for infesting the kernels (Table 3).

TABLE 3. **Count of Insects in Floor Sweepings, on Bags and Baskets and in Cahsew Peels**

Month of observation	*Mean No. of insects in*		*Cashew peels* (100 *g*)
	Floor sweepings (1 m^2 x 3)	*Dust from bags and baskets* (15 g x 3)	
May	19.0 (1 – 57)	15.8 (3 – 25)	42.8 (0 – 140)
June	25.3 (1 – 118)	11.4 (3 – 25)	33.0 (0 – 140)
August	74.0 (22 – 120)	170.0 (14 – 355)	18.2 (3 – 40)
September	45.7 (9 – 122)	37.1 (22 – 81)	21.2 (9 – 37)
October	161.8 (18 – 709)	147.0 (44 – 485)	206.6 (23 – 783)

Relative toxicity of insecticides on *T. castaneum* and *C. cephalonica* was studied. Sprays of (0.1%) methyl parathion, quinalphos and sumicidin were found to be effective against both the insects (Table 4).

Based on the observations presented above the following measures are suggested for preventing infestation of processed cashew kernels packed for marketing.

1. Prompt disposal of rejected kernels and peels.

2. Daily cleaning of processing sheds and burning the sweepings and fortnightly application of insecticides.

3. Use of metal containers in place of jute bags and cane baskets, cleaning baskets and bags once in a week.

4. Storing peeled and graded kernels in closed polythene bags or metal containers.

5. Carrying out the processing of shelling, peeling, grading and packing of kernels in quick succession.

6. Heating of graded kernels before packing if to be stored for prolonged periods.

TABLE 4. **Mortality of Insects - 96 Hours after Spraying (with Diffrerent Insecticides)**

Insecticide and concentration (% a.i.)		*% mortality in*		
		T. castaneum		*C. cephalonica*
		Adult	*Larvae*	*Larvae*
Quinalphos	0.1	100	100	63
	0.05	100	100	40
Fenitrothion	0.1	100	100	27
	0.05	100	83	10
Sumicidin	0.1	100	100	77
	0.05	43	23	70
Fenthion	0.1	100	100	17
	0.05	100	70	7
DDVP	0.1	97	100	7
Phosalone	0.1	100	100	10
Methyl parathion	0.1	100	100	100
Malathion	0.5	100	67	23
Endosulfan	0.1	100	100	20
Carbaryl	0.2	47	40	7
BHC	0.2	Nil	3	3
Baythion	0.2	100	100	13

Acknowledgement

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Host Relationship and Damage Potential of Thrips Infesting Cashew

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Abstract

Both phyllophilous and anthophilous thrips species infesting *Anacardium occidentale* are highly polyphagous enabling consistency of thrips population. *Rhipiphorothrips cruentatus* (Hood), *Selenothrips rubrocinctus* (Giard) and *Retithrips syriacus* (Mayet) infesting leaves tend to show patterns of infestation in relation to water stress as well as the distribution of nutrients. Sizeable populations of inflorescence infesting *Scirtothrips dorsalis* (Hood), *Thrips hawaiiensis* (Morgan) and *Haplothrips ganglbaueri* (Schmutz) cause premature shedding of flowers. The trends of infestation of different species along with some aspects of host plant preferences are discussed.

Introduction

The increase in the incidence of polyphagism in thrips pest species such as *Rhipiphorothrips cruentatus* (Hood), *Selenothrips rubrocinctus* (Giard), *Retithrips syriacus* (Mayet), *Scirtothrips dorsalis* (Hood) and *Haplothrips ganglbaueri* (Schmutz) has become a source of increasing concern in view of the abundance of these species in anacardiaceous plants. Ananthakrishnan (1971 and 1973) had discussed the biology of these species, while Fennah (1964) discussed the nutritional factors associated with seasonal population increase of *Selenothrips rubrocinctus* in cashew in Trinidad. Ananthakrishnan and Muraleedharan (1972 and 1974) also discussed some aspects relating to the host specificity of *Selenothrips rubrocinctus, Rhipiphorothrips cruentatus* and *Retithrips syriacus.* An attempt has been made here to provide an overall picture of the incidence, damage potential and aspects of host specificity in relation to thrips infesting the cashew plant *Anacardium occidentale* in India.

Materials and Methods

Periodical observations on the population density of various species of thrips infesting the leaves were made on 10 leaves approximately of the same stage of development. For an assessment of the species inhabiting the inflorescence two methods were followed, viz. on the basis of 10 beats of the inflorescence on to a white carboard, and also on the basis of the number present per inflorescence by removing them on to a polythene bag and counting them.

Results and Discussion

Principally we have the leaf infesting and inflorescence infesting species, *Rhipiphorothrips cruentatus, Retithrips syriacus* and *Selenothrips rubrocinctus* are essentially leaf inhabiting, while *Scirtothrips dorsalis, Haplothrips ganglbaueri,* and to a very limited extent *Thrips hawaiiensis* are inflorescence inhabiting species. *Selenothrips rubrocinctus* the major thrips pest of cashew in Trinidad, has in recent years come to assume quite some heavy proportions, thus second only to *Rhipiphorothrips cruentatus.* It is of interest to note that *Retithrips syriacus* is slowly making ground as a third species, infesting the leaves. While the discovery of *Rhipiphorothrips cruentatus* in India dates back to 1918, *Selenothrips rubrocinctus* and *Retithrips syriacus* were first noted to occur on *Anacardium occidentale* in 1931 and 1935 respectively. Since the discovery in this country all the three species have become very highly polyphagous mostly infesting myrtaceous and anacardiaceous plants and at the same time maintaining a reservoir on several wild weed hosts, breeding prolifically and enabling easy colonisation on the crop plants. In this connection, mention may be made that Ananthakrishnan (1973) noticed large populations of *Selenothrips rubrocinctus* on a wild species of Jatropha, a common hedge plant all over Kerala, enabling easy migration to the anacardiaceous plants.

Scirtothrips dorsalis has also assumed major proportions in view of their widespread occurrence particularly on *Prosopis spicigera* and species of *Acacia,* as also the polyphagous *Haplothrips ganglbaueri* a typical inflorescence feeder of many host plants. *Thrips hawaiiensis* the true flower thrips has also taken to feeding on *Anacardium occidentale* flowers though to a limited extent.

Immature leaves of cashew are not attacked and heavy infestation results in leaves which are in the process of hardening. Characteristic special distributional patterns of *Rhipiphorothrips cruentatus* and *Selenothrips rubrocinctus* are observed to be distributed at random on leaves suffering from heavy water stress. They also conform to such distinct pattern as 'basalprimary subvascular' (grouped along the sides of the midrib at leaf base) and 'distal primary subvascular' (along the outer margins of the leaf occurring commonly on physiologically old leaves). They feed mostly on the upper surface of the leaf as well, their nymphs being densely gregarious. An essential aspect relates to the increase in the population density of thrips during the dry seasons and the considerable decline with the onset of rains. There appears to be a succession in the population of *R. cruentatus* followed *R. syriacus* in the areas observed around Mardas (Tamil Nadu, India), while *S. rubrocinctus* replaces *R. syriacus* in certain areas of Kerala and Tamil Nadu. Periodical observations indicate the presence of about 70 – 200 individuals of *R. cruentatus* including nymphs and adults per 10 leaves in the early stages of infestation and ranging to a maximum of 230–290 individuals in mature leaves; *R. syriacus* showed a population of 22–108 per 10 leaves, while the population of *S. rubrocinctus* was around 199/10 leaves. *H. ganglbaueri* and *Thrips hawaiiensis* do not appear very commonly in all the inflorescences, but together with *S. dorsalis* they cause the drying up of the inflorescence and shedding of flowers, when the infestation is high. The young fruit is also invariably attacked, the peduncle becoming infested resulting in numerous feeding scars.

All the major species infesting cashew have more or less similar duration of life cycle: *R. syriacus* (12-21 days); *R. cruentatus* (11-21 days); *S. rubrocinctus* (about 23 days); *S. dorsalis* (13-22 days); and *H. ganglbaueri* (15–20 days). Reproduction, both in sexual and parthenogenetic means is very common in all the species. Infected leaves tend to show an increase in the species. Infected leaves tend to show an increase in the concentration, and in some cases, also the number of free amino acids. Ananthakrishnan and Muraleedharan (1972 and 1974) indicate that lower concentration of some of the amino acids may evoke an aggregation response as against the feedling inhibition or host avoidance reaction in higher concentrations. Severely infested leaves of *Anacardium* showed the presence of extra free amino acids such as cystine, lysine, serine, glycine-aspartic acid, not normally present in the non-infested leaves of the same age. The presence of glutamic acid, threonine, proline, alanine, valine-methionine and leucine–isoleusine indicate the high degree of preference and susceptibility of this host to *S. rubrocinctus* and *R. cruentatus*. Fennah (1964) reports the presence of other amino acids such as hydroxyproline and aminobutyric acid. The continued presence of thrips depends largely on the availability of many other amino acids, in sufficient quantities.

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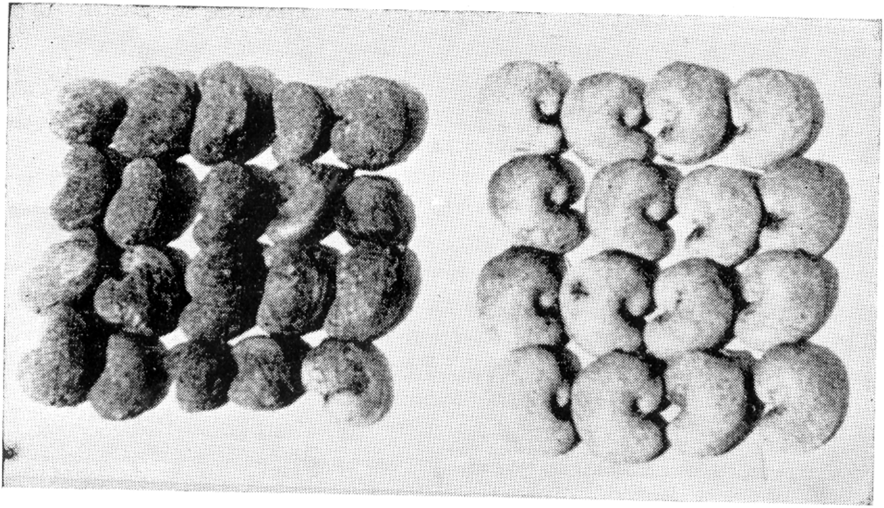
THRIPS DAMAGE



Infected Healthy

An Unusual Occurrence of Thrips on Cashew

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During the survey conducted on insect pests of cashew, two species of thrips viz. flower thrips and leaf thrips were found damaging flowers, floral branches, nuts, apples and leaves of cashew at the Regional Cashewnut Research Station, Vengurla (Maharashtra). Subsequently these thrips were also recorded from cashewnut orchards in adjoining areas.

Although thrips have been recorded on the floral parts and foliage of cashewnut, the pest never assumed serious proportions particularly in the district of Ratnagiri where the crop is extensively grown. However, a very severe incidence of these two species was observed in the months of February and March, 1978. Nymphs and adults were found feeding on the tender portion of leaves, flowers, floral branches, nuts and apples. The rasping and feeding injuries made by thrips results in scabs on floral branches, nut and apples. The cracks were also observed on severely infested apples. Infestation on developing nuts results in the formation of shrivelled, corcky layer on the nuts resulting in malformation (Fig. 1) and immature drop. The affected nuts turned black in colour and were unattractive.

Observation on different cashew cultivars indicated that all cultivars, hybrids and the local types were found to be equally susceptible. About 10 to 15 nymphs and adults could be trapped in a wide-mouthed glass jar with a single finger tap on the floral branch. This indicated that a heavy population of thrips was present on the floral branches. Consequently about 20 per cent nuts developed a corcky layer on them at the time of harvest.

Application of 0.05 per cent endosulfan as spray given for tea mosquito control at the time of emergence of foliage, emergence of panicle and fruit set was not effective to prevent thrips infestation. Hence, an additional spray of 0.05 per cent quinalphos had to be given in order to control the pest.

Discussion

G.B. Pillai: I would like to know whether any data on immature fruit drop due to thrips infestation (flower thrips) have been collected at Vengurla?

P.D. Patil: In the present study the aspect like population fluctuation and nature of damage were only undertaken.

Integrated Control of Cashew Stem and Root Borer *Plocaederus ferrugineus* L

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Abstract

Among the numerous insect pests infesting cashew, stem and root borer, *Plocaederus ferrugineus* L. is the most dreaded one since its infestation results in the death of the tree. Collection of the pest in different stages and destroying them, followed by application of BHC 10 per cent dust to the soil and 0.1 per cent spray to the trunk gives 100 per cent control of the pest even in the advance stages of infestation. Various methods adopted for an effective control of the pest by adopting an integrated approach are discussed.

Introduction

In Andhra Pradesh cashew plant is infested by as many as 20 insect pests during the various phases of its growth (Ayyanna, Narayana and Krishnamurthy Rao, 1977). Among these the tree borer *Plocaederus ferrugineus* L. is a major and serious pest, killing the infested tree and is observed to be present in all the cashew growing regions of the state.

The pest is prevalent throughout India causing considerable damage to the crop. Eventhough many workers have suggested different control measures, information on a large scale control in the field is not available in literature. Pillai, Dubey and Vijay Singh (1976) reviewed the work done on control aspect of this pest in India and reported that though many insecticides are found quite effective in controlling the grub, the trees in the medium and advanced stages of infestation cannot be saved.

Materials and Methods

An adaptive research trial was laid out for control of *P. ferrugineus* of cashew adopting an integrated approach. The following pest control methods were investigated.

1. *Mechanical:* Removal of the pest mechanically (larvae, pupae and adults) and destroying them.

2. *Chemical:* (a) Application of BHC 10 per cent dust by incorporating in the soil around the base of the trunk and roots.

(b) Application of 0.1 per cent BHC spray to the trunk upto a height of 1 m from the ground level.

In the first instance the entire plantation was surveyed and the borer infested trees were identified. Out of 16,209 trees existing in the plantation, 809 trees were identified and marked during 1976–77. A trained person was employed for identification and mechanical removal of the pest. The control operations were taken during the month of June and July.

Periodical observations were made on the efficacy of the treatments and the results are presented in this paper.

Results and Discussion

The adult beetle always lays eggs in the loose bark of the trunk upto a height of 1 m from the ground level or on exposed roots. The grubs after hatching feed on the soft tissues moving downward towards the roots, but never bores or moves upward towards the top. Taking advantage of this habit of the pest, it was very easy to locate the pest inside the tree and collect its various stages by removing the bark along the route of its path, which under bored or tunnelled condition gives a hollow sound on tapping.

In the present investigation from a single tree, a maximum of 15 beetles in different stages (grubs, pupae and adult beetles) were collected. The operation was continued daily and the various stages of the pest collected were destroyed. The details are presented in Table 1.

TABLE 1. **Borer Infestation in Cashew Plantations of Forest Department at Perali**

No. of trees	*No. of trees infested*		*No. of larvae, pupae and adults collected mechanically*	
	1976–77	1977–78	1976–77	1977–78
16,209	809	442	2,174	1,651

After the grubs, pupae and beetles were collected mechanically as detailed above, the trees were treated with BHC 10 per cent dust. The insecticide was applied around the trunk and roots by making trenches and also incorporated in the soil so as to control the early instar larvae if any left out unnoticed. Further the trees were sprayed with 0.1 per cent BHC upto a height of 1 m from the ground level.

Adoption of these two methods turned out to be highly effective and the trees which were severely infested by the pest and showing symptoms of partial drying, survived and put forth new growth and vigour and gave good yields. The cost involved for operating these two control measures was only Rs. 0.99 per tree.

It is suggested that a co-operative approach among all the cashew growers of the locality is indispensible to operate the control measures simultaneously and in contiguous blocks since the adult beetles migrate and render the control measures operated in pockets or in scattered orchards ineffective and futile.

Acknowledgement

The authors are highly grateful to M/S. Krishnananda Rao and Linga Reddy, Forest Range Officers, Bapatla and Shri Panduranga Reddy, Divisional Forest Officer, Guntur for the keen interest and help extended in conducting the investigation.

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Discussion

C.C. Abraham: Did you try curative methods such as injection of toxicants into the tunnels against the stem border?

K.L. Narayana: In the adaptive trial injection methods was not tried. However, I may add, that in another experiment some of the insecticides like DDVP 0.05 per cent. B.H.C. 0.1 per cent, endosulfan 0.05 per cent were tried and were found to be effective especially when the borer was in the superficial layers and the tunnels made were comparatively almost straight and short.

C. Patro: Do you think that it will be possible to apply some fumigants like carbaryl or any other insecticide and seal the opening made by the borer. If so is it possible in a field scale?

K. L. Narayana: Some chemicals like aluminium phosphide (celphos), DDVP were tried by introducing into the bores and plugging. Some positive results obtained revealed the efficacy of the chemicals in killing the grubs *in situ*. On a large scale, the introduction of fumigants was not tried.

Disease and Pest Problems of Cashew in Malaysia

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Abstract

In Malaysia, cashew is grown mainly on poor, sandy, marine alluvial soil in the east coast of the Peninsula. Investigations on the failure of fruit setting in bearing trees in plantation holdings in Trengganu and Pahang revealed that the major problems of the cashew crop were not agronomical but rather pathological and entomological in nature. Barreness of trees was found to be due to severe blossom blight and dieback diseases. A spray programme comprising a mixture of fungicide (mancozeb), insecticide (dicrotophos), and a foliar fertiliser surmounted both disease and pest problems and resulted in a significant increase in yield and fruit set.

Introduction

In late 1977 our attention, was called upon to the low yield and failure of fruit setting of cashew trees in Cashew Industry of Malaysia Association (CIMA) plantation holdings in the east coast states of Trengganu and Pahang. Our investigations revealed that the major problems of the cashew stand in these areas were not agronomical but rather pathological and entomological in nature. The fruit bearing trees had lush foliage and exhibited profuse flowering with little signs of nutrient or water stress relfecting good agronomical practices. Very little information is available on the status of local diseases of cashew (Singh, 1973), though some information on the local pests (Yunus and Ho Thian Hua, 1970) has been documented. In this paper the symptoms and causes of local diseases and pests of cashew in Malaysia and results of a preliminary pesticide trial are presented.

Materials and Methods

A survey of pest and disease occurrences was carried out in all the CIMA plantings visited. Diseased specimens and insect pests were collected for isolation and identification purposes. Whenever possible pathogenicity tests were carried out with pure isolates of microorganisms isolated from diseased specimens. Cultures of microorganisms were sent to the Commonwealth Mycological Institute and insect specimens to the British Museum for identification.

Due to the magnitude of the problem a preliminary trial was conducted two weeks after the first visit on four year old trees (fruit-bearing age) in Trengganu. A triple mixture combination of (i) a fungicide (maneb) + zinc ion co-ordination product (Manzate-D – 80% WP), (ii) an insecticide – dicrotophos (Bidrin – 24% EC) and (iii) a foliar fertilizer, welgrow standard containing 15 parts N: 30 parts P: 15 parts K and seven trace elements and a CF 55 penetrant were used. The mixture was used at the rate of 0.2% a.i. 0.05 % a.i. and 9g/4.5 litres respectively. A high volume spray was adopted using a Maruyama power sprayer with a universal nozzle spray gun. Each tree received 4.5 litres of the triple mixture. Two sprays were given once during flowering and a subsequent spray four weeks later. One block of trees (M) was sprayed with the above mixture, another block (W) was sprayed with water and another block (C) was used as unsprayed control. Approximately 1.62 ha were sprayed per day.

Results and Discussion

A survey of the pest and disease occurrences in all CIMA plantings revealed that diseases were significantly more important than insect pests. These diseases referred to as floral shoot dieback, blossom blight, fruit spot and rot were very wide-spread and rampant in varying magnitudes in all the plantings surveyed, were responsible for failure in fruit setting. Poor fruit set and low yields were particularly acute in too dense plantings where the very humid environment was conducive to the development and spread of these diseases. Pest and disease control operations were difficult in dense population due to lack of manoeuvrability of spraying machines.

Dense plantings also had a higher incidence of leaf diseases such as sooty mould and algal leaf spot. However, leaf diseases assume a very minor role in yield reduction in cashew.

Blossom blight and floral shoot dieback : Blossom blight is characterized by blackening and withering of petals and other floral parts. Floral shoot dieback begins with progressive dieback of small peduncles which usually start from the tips by subsequent shrivelling and drying up of whole inflorescence. In less severe cases, black necrotic spots on the peduncle and main shoot were observed. *Phomopsis anacardii* (Early and Punith.) and a *Colletotrichum* state of *Glomerulla cingulata* (Stonem.) were consistently isolated from blighted blossoms and floral shoots and peduncles. *Botrytis* sp., was also isolated from blighted blosoms. Pathogenicity tests on detached inflorescences revealed *Colletotrichum* to be the more important pathogen.

Fruit spot and rot : Fruit spot is characterized by black sunken spots on the immature green nuts and apples. A severe attack results in complete decay of the fruit. *Colletotrichum* sp. was found to be the casual organism.

Vegetative shoot dieback: This involves the progressive dieback from the tip downwards of young vegetative shoots. *Pestalotiopsis versicolor* (Speg.) Steyeart, *Phomopsis anacardii* (Early and Punith.) and a *Colletotrichum* state of *Glomerulla cingulata* (Stonem.) were associated with this disease. This differs from the dieback caused by insects, where punctured holes occur at the base of a blighted young shoots.

Leaf diseases: One common disease affecting leaves is the black leaf spot. This is characterized by black pin-head spots on the upper surface of matures leaves. *Phyllosticta anacardicola* (Batista and Vital) was consistently isolated from the necrotic spots. Other leaf disease encountered were sooty mould caused by *Meliola anacardii,* (Zimm.) algal leaf spot by *Cephaleuros virescens* and back blotch disease by an unidentified fungus.

Insect pests: Minot wounds and injuries from insect attack were observed on the fruit and shoot and these may serve as points for pathogenic microorganisms. Two groups were found to cause quite severe damage to leaves of the cashew tree, fortunately their attack was not widespread. The web worm, *Orthaga incarusalis* Walk, webs leaves together, feed on the leaves and the leaves dry up. The other group is the blister miners a member of Gelechiidae family which forms blisters on the epidermis. Other pests observed in sporadic instances are listed in Table 1.

The results of the spray trial are given in Table 2. Trees sprayed with water had the highest incidence of blighted inflorescences. A random assessment of disease incidence at two months after first spraying showed that the majority of unsprayed trees had about 64 per cent of blighted inflorescence and the water-sprayed trees had about 78 per cent. Trees sprayed with the triple mixture had less than 10 per cent of blighted inflorescences. Besides the increase in nut production, trees receiving the triple mixture spray produced better quality nuts which were heavier and more plumpy (90 nuts/ 455 g.) than the other treatments. In addition these trees had less fruit abortion and better foliage growth.

Thus the results indicate that to increase yield in cashew production, trees have to be sprayed sequantially with pesticides and a foliar fertiliser. Presumably the fungicide keeps the disease in check, and the insecticide halts the probable dissemination of pathogenic microorganisms by insects, whilst the foliar fertilizer overcomes the problems of leaching and run-off in such freely drained sandy soil. Besides, the saving in operation and labour cost a synergistic effect is also indicated by combining pesticides. Far from surmounting the problem of failure in fruit set, spraying trees with water enhanced the problem manifold and was exceedingly detrimental to good growth of inflorescence and subsequent yield.

TABLE 1. **Pests of Cashew in CIMA Plantations in Pahang and Trengganu**

Plant Part	*Pest*	*Taxonomy*
Root	*Coptotermes curvignathus* Holmgr.	Isoptera : Termitidae
Stem	*Rhytidogera simulans*, White	Coleoptera : Cerambycidae
Leaves	*Attacus atalas*, L.	Lepidoptera : Saturnidae
	Egropa malayensis, Dist.	Hemiptera : Membracidae
	Blister miners	Lepidoptera : Gelechiidae
	Orthaga inearusatis, Walk.	Lepidoptera : Pyralidae
	Lepidiota stigma, F.	Coleoptera : Scarabaeidae
Flower	*Egropa malayensia*, Dist.	Hemiptera : Membracidae
	Flea beetles	Coleoptera : Chrysomelidae
	Black ants	Isoptera : Formicidae
	Flies	Diptera : Muscidae
Fruit	*Egropa malayensis*, Dist.	Hemiptera : Membracidae
	Rhopalosiphum sp.	Hemiptera : Aphidae
	Black ants	Isoptera : Formicidae
	Carpophilus sp.	Coleoptera : Scolytidae

TABLE 2. **Effect of Pesticide Spraying on Cashewnut Production**

Block	*Treatment*	*Total No. of trees*	*Density/ ha*	*Net weight kg*	*Average production kg/ha*	*No. of nuts per 455 g*
W	Water	49,323	244	126.4	40.55	105
C	Control	46,348	235	732.2	3.12	100
M	Fungicide, insecticide and fertilizer mixture	27,647	222	5950.0	40.52	90

Acknowledgement

We thank the Managing Director of FIMA and the plantation managers of CIMA plantations in Trengganu and Pahang for their cooperation and technical assistance and the Director and staff of the Commonwealth Mycological Institute and British Museum for their help in Identification of the fungal cultures.

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Discussion

Abi Cheeran: (1) When does the die-back disease usually appear in Malaysia? (2) Does the die-back and blossom blight incidence occur at the same time?

T.K. Lim: (1) Severe during flowering and (2) Yes.

K. Koyamu: It was said that NPK alone was given with insecticides and fungicides by foliar application. I presume that only N and K will be effective when given by foliar application and not P. Have you tested this?

T.K. Lim: The fertilizer used contain soluble N, P and K and the CF 55 penetrant, we believed is responsible for its rapid absorption by the plant.

Sujan Singh: Have any studies been done in Malaysia to determine the impact of anthracnose disease on yield of cashew?

T.K. Lim: A cost benefit trial to assess impact of anthracnose disease on yield has just been initiated.

K.K.N. Nambiar: (1) What is the net loss due to the foliar diseases which you have enumerated? Does your data substantiate the view that diseases are more important than pests in cashew, (2) The symptoms of black blotch seem to be similar to the rotting symptoms on leaves we observe here due to *Cylindrocladium*. Which is the season in which you observed this disease? (3) Have you taken up any pathogenicity trials using the fungi isolated with and without the usual insect visitors on the inflorescence and established their pathogenicity?

T.K. Lim: (1) We have not carried out any studies on losses due to foliar diseases, but survey and preliminary trials have shown that floral diseases can cause marked reduction in yield (2) During the flowering season, (3) Not with insects. Dissemination of diseases by insects visiting the inflorescence is in our research programme.

J.G. Ohler: I have the impression that most of the cashew diseases you mentioned are favoured by a humid climate. Are you of the opinion that the disease incidence might be prohibitive for economic cashew growing in the area?

T.K. Lim: (1) A humid environment favours development and spread of diseases on all crops in Malaysia. With sound orchard and pest management strategies diseases will not be a limiting factor as can be seen in our rubber, cacao and oil palm plantations.

Y.R. Sarma: Did you establish the pathogenicity of *Phomopsis* and *Colletotrichum* isolated from blossom blight affected cashew. (2) Did you notice any insect association with the blossom blight?

T.K. Lim: (1) Pathogenicity tests revealed that *Colletotrichum* was more important than *Phomopsis* as the former caused similar symptoms on uninjured and injured inflorescences and the latter only on injured inflorescences (secondary organism). (2) Insects were observed visiting blighted and clean inflorescences indicating that they may be disseminating spores of the pathogen.

C.C. Abraham: Does *Helopeltis* spp. occur on crops such as cacao, tea, etc. in Malaysia? It is quite likely that *Helopeltis* is associated with blossom blight in the country.

T.K. Lim: *Helopeltis* is very important pest on cacao and to some extent in tea. Upto now, we have not observed any *Helopeltis* or its attack on cashew in the plantings. But with increasing cultivation of cacao encroching nearer to cashew areas this pest and other sucking pests may pose problems.

Leaf Rot of Cashew Caused by *Cylindrocladium quinquiseptatum*, Boedijin and Reitsma

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Abstract

Leaf rot of cashew caused by *C. quinquiseptatum* was noticed both in plains as well as in hilly tracts of Cannanore and Calicut districts of Kerala during August-October period. Among the 19 hosts belonging to 8 families, 13 hosts belonging to 7 families were found to be infective. The isolates of *C. quinquiseptatum* from cashew, clove and eucalyptus are cross inoculable. This fungus is recorded on cashew for the first time in India.

Introduction

Cashew (*Anacardium occidentale* L.) one of the most important commercial tree crops grown both on the plains as well as on the hilly tracts in Kerala. The disease problems of cashew in India were recently reviewed (Nambiar, 1978). Leaf spot disease caused by *Phyllosticta anacardii* (Early and Punithalingam, 1972), anthracnose disease caused by *Colletotrichum gleosporoides* Penz., (Sujan Singh et al., 1967) and *Phytophthora nicotianae* var. *nicotianae* (Thankamma, 1974) are some of the important foliar diseases recorded on cashew. The leaf rot disease of cashew in the hilly tract of Anamanjalamkaya near Kasaragod was noticed. The disease was also noticed on the plains both in Cannanore and Calicut districts of Kerala.

Materials and Methods

Clean infected leaves collected from the field were washed thoroughly under running tap water, later with sterile water and incubated in humid chambers to induce sporulation. Sporulating masses were touched with the tip of sterile needle and streaked on plane agar. Later the germinating spores were picked up with a sterile loop and cultured on potato sucrose agar (PSA) and oats agar (OA) media. Spore germination studies were conducted with distilled water and cashew leaf leachate as the germinating medium. The slides with spore drops were incubated in humid petri plates at 26–28 °C.

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Pathogenicity tests were conducted under field conditions by applying spore suspensions on the lower surface of the leaves of test plants and the branches were covered with polythene bags to ensure high humidity. In another set, spore suspension was applied on upper surface also. This procedure was also followed for host range studies. Cross inoculation studies with *C. quinquiseptatum* isolates from cashew, clove and eucalyptus were conducted by applying spore suspension on the lower side of the leaves of the test hosts and kept in humid petriplates incubated at 26–28 °C.

Results and Discussion

The disease started appearing during August-September period and was seen upto October when temperatures were 25–28 °C. Initially the symptoms appeared as minute light olive coloured necrotic spots on the lower surface of the leaves. Later well discernible brownish lesions enlarged rapidly and adjacent lesions coalesced forming necrotic patches. Often the lesions on the margin coalesced exhibiting symptoms of marginal necrosis, which progressed inwards (Fig. 1). Tender twigs also showed dark lesions. Infected leaves dropped off causing moderate to severe defoliation. The examination of fallen leaves showed cream to light greyish coloured sporulating masses of the fungus on the lower side. The spread of the disease was rapid when intermittent showers occurred probably due to rain splashing aiding in spore dispersal.

The fungus grew well and sporulated abundantly on potato sucrose agar medium. A mature colony of 6–8 days showed distinct narrow light coloured zones alternating with brownish coloured zones. Secretion of a brown pigment was noticed both on solid and liquid media. Sclerotia with dark brown thick walled cells were noticed in older cultures. Conidiophores appeared on lower surface of the leaves either alone or in groups. The conidiophores were straight, septate, measuring 132–244 μ in height and 4.7 to 7.14 μ in width. The primary branches measure 13.0–23.8 x 2.3 – 4.7 μ and secondary branches 9.5–19.0 x 2.3 – 4.7 μ. Tertiary branches were not noticed. Each bracnh had 2–4 phialides measuring 9.5–16.6 x 2.3–4.7 μ giving off conidia. The conidiphore axis ends in a sterile thread measuring 120 – 300 μ with a terminal club shaped structure measuring 4.0–5.7 μ in width. The conidia appeared in masses glued together measuring 52.1–110.8 x 4.7–7.2 μ. The mature spores were consistently five septate although 3–4 septate immature conidia were also noticed.

Spore germination was noticed both from terminal and inter-calary cells (Fig. 2). Spore germination was noticed within hours in cashew leaf leachate medium as against 7–8 hr in distilled water. Germination was 86 per cent in the former and 39 per cent in the latter by 12 hrs. However, it

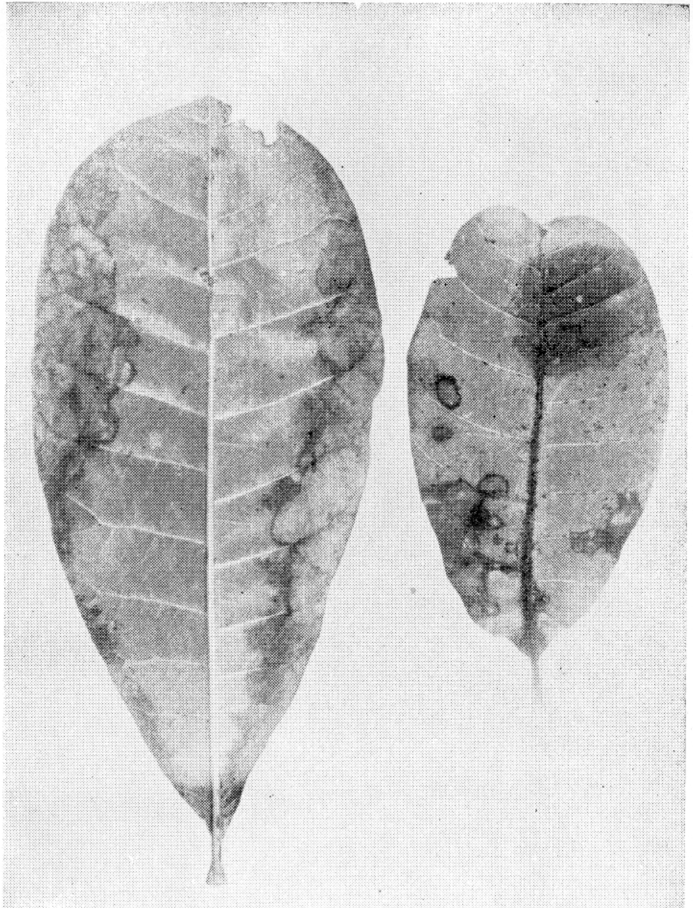

Fig. 1. *Cylindrocladium* infected Cashew leaves.

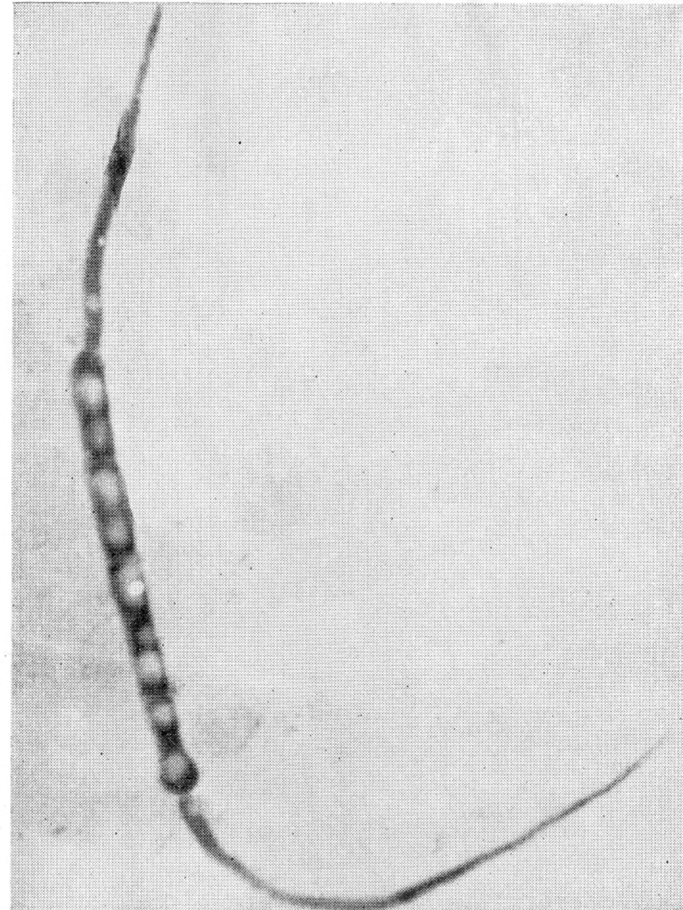

Fig. 2. *Cylindrocladium* — polar germination of spore.

increased to 97 per cent and 93 per cent respectively by 24 hrs. Early germination in the leaf leachate indicates the presence of a water soluble substance on the host surface stimulatory to germination and might play an important role in host parasite interactions.

TABLE 1. **Host Range of *Cylindrocladium quinquiseptatum* Development.**

S.No.	Host	Symptom	
		Leaf rot	*Leaf spot*
1.	*Anacardium occidentale*	+	+
2.	*Mangifera indica*	+	+
3.	*Theobroma cacao*	—	+
4.	*Eucalyptus grandis*	+	+
5.	*Eugenia caryophyllus*	+	+
6.	*Dolichos lablab*	—	+
7.	*Desmodium utilissimum*	—	+
8.	*Vigna unguiculata*	—	—
9.	*Stizolobium niveum*	—	—
10.	*Manihot utilissima*	—	+
11.	*Ipomea batata*	—	—
12.	*Piper nigrum*	—	+
13.	*Piper longum*	—	+
14.	*Zingiber officinale*	—	+
15.	*Curcuma longa*	—	+
16.	*Elettaria cardamomum*	—	+
17.	*Aframomum melegueta*	—	—
18.	*Brachiaria ruzziensis*	—	—
19.	*Tripsacum laxum*	—	—

+ Pathogenicity positive; — Pathogenicity negative

In the case of cashew and mango the leaves showed initial necrotic spots by 48 hrs. Younger leaves were more susceptible than mature ones. Inoculation on the lower surface induced lesions which enlarged subsequently. However, when the spore suspension was applied on the upper surface of the leaf, the lesions were small and necrotic and did not enlarge. Among the 19 hosts tested belonging to 8 families, 13 hosts belong to 7 families were found to be susceptible (Table 1). Out of these 13 hosts, mango, clove and eucalyptus exhibited leaf rot and leaf spot symptoms, whereas the rest of the hosts showed only necrotic spots of 1–2 mm size which did not enlarge further. Cross inoculation tests on excised leaves with isolates from cashew, clove and eucalyptus were positive. The enlargement of lesions was rapid on the leaves of cashew, clove and eucalyptus when inoculated with isolates from cashew and clove. However, the enlargement of lesions was slow on these hosts when the isolates from eucalyputs were used. From the perusal of the literature it was found that there was a close morphological similarity among these isolates. This finding is of considerable significance from the epidemiological point of view.

Boedijin and Reitsma (1950) reported *C. quinquiseptstum* on leaves of clove seedlings at Tzimas near Bogor. In India this fungus has been recorded on *Eucalyptus grandis* and 12 other species of eucalyptus (Seghal, Nair and Jagadeesh, 1975) and also on clove (Sarma and Nambiar, 1978). *Calonectria quinquiseptata*, the perfect stage of the pathogen has been reported on eucalyptus in Brazil (Figueiredo and Namekata, 1967). However, the authors did not notice the perfect state either on cashew or clove. This is the first record of *C. quinquiseptatum* on cashew in India.

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PROCESSING AND TECHNOLOGY

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Utilization of Cashew Apples for the Development of Processed Products

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Abstract

Cashew apples are an important by-product of cashewnut industry. Most of the fruits, at present, are not utilised in the country. Cashew apples contain astringent and acrid principles which produce an unpleasant biting sensation on the tongue and throat when eaten as such. The fruits are highly susceptible to injury and rapid microbial deterioration. These factors together with the difficulties experienced in collection of fruits have come in the way of commercial utilization of this nutritious fruit. It has been found possible to remove astringent principles by simple methods like steaming, brine curing or by chemical treatment and then utilize the fruit for conversion into several edible products. These products include clarified and cloudy cashew apple juice, cashew apple juice blended with other fruit juices and pulps like lime, pineapple, orange, mango, and papaya, cashew apple juice concentrate, cashew apple preserve and candy, cashew apple jam, cashew apple mixed fruit jam, cashew apple pickle and chutney etc. Work done on the development of these products and their storage behaviour are reviewed and presented in this paper.

Cashew apples are an important by-product of cashewnut industry. The yield of cashew apple is four to five times that of cashewnut. Most of the fruits at preset are not utilised in the country except for a small quantity (about 15%) used for direct consumption or for production of country liquor (Sondhi, 1962).

Cashew apples contain astringent and acrid principles which produce an unpleasant biting sensation on the tongue and throat when eaten as such. The fruits are highly susceptible to injury and rapid microbial deterioration. These factors together with the difficulties experienced in collection of fruits have come in the way of commercial utilisation of this nutritious fruit.

Investigations have been carried out at Central Food Technological Research Institute to utilise these fruits for conversion into several edible products. These products include clarified and cloudy cashew apple juice, blended juice beverages, cashew apple juice concentrate, cashew apple preserve and candy, cashew apple jam and mixed fruit jam, pickles, chutney, canned products etc. Work done on the development of these products and their storage behaviour are reviewed and presented in this paper.

Characteristics of the fruit : Cashew apple is a swollen peduncle to which the nut is attached. It is a soft but fibrous juicy fruit. It possesses exotic flavour characteristic of the fruit. Based on external colour of the fruit cashew apples can be broadly classified into Red and Yellow varieties. (Sondhi, 1962).

Data on the physico-chemical composition of the juice just expressed from ripe Red and Yellow varieties of cashew apples from Kerala and Karnataka region are presented in table 1. The fruit weight varies from 26 to 50 g and the yield of juice 60 – 70 per cent. The pH of the juice ranges from 3.9 to 4.1. The total soluble solid contents ranges 12 – 13 per cent and the acidity from 0.2 to 0.35 per cent. The juice is rich in vitamin C and it ranges from 120 to 200 mg/100 g. The tannin content is between 0.3 to 0.5 per cent. The astringent and acrid taste of the fruit has been attributed to its tannin and an oily substance present in the fruit although the nature of the oily substance is not identified (Jain, Das and Girdharilal, 1954).

TABLE 1. **Physico-Chemical Composition of Cashew Apple Juice**

Physico-chemical characteristics	*Kerala*		*Karnataka*	
	Red fruits	*Yellow fruits*	*Red fruits*	*Yellow fruits*
Fruit weight (g)	50.2	50.5	26.1	46.2
Juice yield %	71.2	72.4	69.8	72.2
pH	3.9	4.0	3.9	4.1
Total soluble solids %	12.6	11.8	12.3	12.2
Acidity (as malic acid) %	0.19	0.20	0.35	0.32
True ascorbic acid (mg/100 g)	117	126	200	153
Total sugars %	8.7	8.3	8.4	8.0
Total tannins %	0.34	0.35	0.55	0.45

Leucodelphinidin has been identified as the major polyphenol constituent of cashew apple juice by Sastry et al. (1962). Ascorbic acid and total polyphenol content are the two important factors from the point of view of processing cashew apples. Sastry et al. (1962) reported about the regional variation in the tannins and ascorbic contents of red and yellow varieties of cashew apples (Table 2). The tannin content varied from 0.1 to 0.7 per cent. Hence the gelatin requirement may vary depending upon the tannin content during clarification of the juice. The ascorbic acid content varied from 170–306 mg/100 g.

TABLE 2. **Regional Variation in Tannin and Ascorbic Acid Contents of Cashew Apple (Red and Yellow Varieties)**

Region	*No. of samples analysed*	*Tannins in expressed juice (g/100 cc)*		*Ascrobic acid in expressed juice (mg/100cc)*
		Total	*True*	
Mysore	28	0.4 — 0.7	0.30 — 0.50	180 — 250
Ullal	20	0.32 — 0.69	0.12 — 0.50	192 — 306
Trichur	18	0.10 — 0.28	0.01 — 0.10	170 — 250

Removal of astringent and acrid principles : One of the major problems in the utilisation of cashew apple for edible purposes is its astringent and acrid principles. Hence various methods have been tried to remove these unagreeable principles. Out of these three methods have been found to be satisfactory in the preparation of different products (Jain et al. 1951 and Jain, Das and Girdharilal, 1954). These include (i) steaming of the fruit for 5 minutes under the steam pressure of 5 psi and subsequently thorough washing of the steamed fruits with cold water (ii) cooking of the fruit for 5 minutes in boiling solution of common salt (2%) and (iii) by addition of required quantity of gelatin solution to the juice expressed from the fresh fruit.

Effect of these treatments on the quality of the expressed juice are presented in table 3. Though the juice obtained from the fruit cooked in brine was almost devoid of astringency it was saltish in taste and lacked the characteristic flavour. In the case of steamed fruit, the juice obtained had slight astringency but had good flavour. They showed that even this slight astringency could be eliminated by the addition of small quantity of gelatin to the expressed juice.

Chakrabarthy (1961) reported higher recovery (68%) of juice by employing screw type juice extractor than that obtained by basket press (38%). The juice obtained by basket press contained less tannins and consequently required less gelatin for clarification.

TABLE 3 **Effect of Steaming and Cooking in Salt Solution on the Quality of the Juice**

	Expressed juice from		
	Fresh fruit	*Steamed fruit*	*Fruit cooked in brine*
Total soluble solids %	14.2	13.4	13.4
Acidity (as malic acid) %	0.3	0.4	0.4
Tannins %	0.3	0.07	0.04
Taste and aroma	Astringent	Slight astringency	Free from astringency

However steaming of the fruit and then crushing the fruit first in a screw type juice extractor and then pressing the residue again in the basket press has been recommended for better yield and quality of the juice. Quick freezing and thawing of the fruit before extraction has been found to be advantageous (Rama Rao, Balakrishna and Rajagopalan, 1952) in getting 14 per cent more juice containing more ascorbic acid. But it may add to the cost of production.

Chakrabarthy (1961) has also described the method for removing astringent principles by precipitation with gelatin followed by filtration through filter press after adding filter aid. Physico-chemical characteristics of the juice samples before and after gelatin treatment are presented in table 4. Gelatin precipitation and clarification of the juice reduced the acidity and to some extent ascorbic acid content of the juice. This is mostly due to the dilution effect.

Based on the above work the following procedure is recommended for production of cloudy and clarified juices from cashew apple.

Clarified juice : The fruits after washing are passed through the screw type juice extractor and the residue is further pressed out in a basket press. Juice obtained are mixed together and required quantity of gelatin solution (5%) added to precipitate the tannins. After the precipitate has settled the supernatant is siphoned off, mixed with filter aid (0.2% supercell) and then passed through the filter press to obtain the clarified juice. Sugar and citric acid are added to the juice to raise its Brix to 15° and acidity to 0.4 per cent. The juice is then heated to 35 °C filled immediately into 6 oz. bottles crown corked and processed for 20 minutes at 80–85 °C. The bottles are then air cooled and stored in a cool place.

TABLE 4. **Physico-Chemical Characteristics of Juice Samples Before and After Gelatin Treatment**

	Before gelatin treatment	*After gelatin treatment and clarification*
1. Total soluble solids %	12.50	10.50
2. Acidity %	0.46	0.33
3. pH	4.25	4.20
4. Ascorbic acid (mg/100 ml)	264.00	219.00
5. Tannins %	0.32	0.03

Cloudy juice: The fruits are steamed for 5 minutes at 5 psi followed by cooling and washing. The juice is expressed as above and treated with required quantity of gelatin. The precipitate formed is separated by passing through thick cloth. The juice thus obtained is formulated and preserved like the clarified juice.

Juice Blends : The cashew apple juice prepared as above can be blended with other fruit juices to produce mixed beverages of greater appeal. Hence Jain, Das and Girdharilal (1954) recommended blending of cashew apple juice with juices like lime, pineapple, orange, grape and apple. Cashew apple juice, sugar and water mixed in the proportion of 18: 2 : 25 is reported to give a good carbonated beverage. They have also described the method of preparing spices beverage using cashew apple juice and other common spices like clove, cumin, pepper, cardamom, ginger etc.

Effect of storage on the ascorbic acid and colour development in bottled cashew apple juices with and without blending with other fruit juices was studied (Chakrabarthy, 1961). The losses of ascorbic acid in cashew apple juice and its blends amount to around 25 per cent after four months storage at 37 °C. Colour development was found to be rapid in the case of unclarified juice as compared to the clarified juice and blended juices. The bottled products were found to be still acceptable at the end of four months storage period.

Cashew apple juice is rich in vitamin C but reported to be a poor source of carotene (0.32 mg/100 g). It was therefore considered desirable to blend cashew apple juice with carotene rich fruit pulps like mango and papaya pulps (Sondhi, 1962). Such blended juices were found to be quite acceptable even after five months storage at room temperature.

Cashew apple juice concentrate : Six fold concentrate prepared from the apple juice would be naturally highly nutritious and could be utilised in the preparation of aerated drinks. Chakrabarthy (1961) and Pruthi et al. (1963) conducted studies on the preparation and storage of cashew apple juice concentrate from both clarified and cloudy juices. Vaccuum concentration was found to give naturally a better product than open pan concentration. Data on physico-chemical changes during concentration of cashew apple juice (cloudy as well as clarified juices) using a forced circulation evaporator is shown in table 5. Retention of ascorbic acid was slightly better in unclarified juice than the clarified juice although the latter yielded a concentrate with comparatively better odour and flavour. The viscosity of the concentrate prepared from unclarified juice was found to be four times that of the concentrate prepared from clarified juice.

TABLE 5. **Physico-Chemical Changes During Concentration of Cashew Apple Juice Using a Forced Circulation Evaporator**

	Unclarified juice		*Clarified juice*	
	Before concentration	*After concentration*	*Before concentration*	*After concentration*
Refractometer solids %	12.0	77.0	9.0	71.0
Acidity as malic acid %	0.4	2.6	0.36	2.1
pH	4.1	4.0	4.3	4.1
Viscosity (CP)	20.0	1820	20.0	450
Ascorbic acid mg %	250.0	1423	192.6	1108
Reductones % Ascorbic acid	25.0	14.5	17.6	11.5
% Retention of ascorbic acid	—	85.0	—	78.0
Colour	Light yellow	Dark brown	Light yellow	Brown
Flavour	Characteristic cashew apple flavour	Mild cashew apple flavour	Characteristic cashew apple flavour	Mild cashew apple flavour

Addition of 1000 ppm of SO_2 especially at the stage of two fold concentration was found to be helpful in reducing browning considerably (Pruthi et al. 1963). The concentrate thus prepared was found to keep well for 16 weeks at room temperature (24–30 °C).

Cashew apple preserves and candy : For preparing good quality preserve and candy from cashew apple ripe cashew apples are washed and immersed in 2 per cent salt solution and the concentration of salt is raised by 2" every day until it reaches 10 per cent. At this stage 600 ppm of KMS added and stored for two more days. The fruits are then removed and washed thoroughly in water and steamed for 5 minutes under steam pressure for 5 psi. The steamed fruits are cooled by immersing in water and each fruit is pricked all around the surface of the fruit and also the ends of the frit trimmed off. The actual candying process is then carried out as usual starting with a 30° Brix syrup containing 0.1 per cent citric acid and finished when the final syrup strength is 70° Brix. The acidity of the syrup and the time of boiling are regulated and controlled every day to keep the reducing sugars in the syrup at a level of about 25 per cent. The finished product could be packed in syrup and sold as preserve or dried and packed to be sold as candy.

Cashew apple and mixed jam : Jain , Das and Girdharilal (1954) described the method of making cashew apple jam and mixed fruit jam using cured cashew apples. According to this method the fruit is treated in 2 per cent salt solution for three days followed by washing. It is then steamed for 15 minutes under steam pressure of 10 psi, cooled and washed. The fruits are sliced, mixed with equal quantity of sugar and cooked to the jam consistency. Citric acid at 0.3 per cent level with respect to prepared fruit is added towards the end of cooking process.

They also reported about preparing good quality mixed fruit jam by mixing with cashew apple pulp, an equal quantity of banana pulp or pineapple pulp.

Cashew apple chutney : Cashew apple is found to be quite suitable for preparing fruit chutney as reported by Jain and Girdharilal (1955). The fruit pieces are prepared in the same way as for jam and then used for chutney making.

Other products : Jain, Das and Girdharilal (1954) have also indicated the possibilities of using ripe cashew apple for canning in syrup and raw green fruit after suitably treating them for making pickle and for preparing canned curried vegetables in combination with potatoes and tomatoes.

Cashew apple residue left after juice extraction accounts for 30–40 per cent of the whole fruit. Chakrabarthy (1961) and Sondhi (1962) conducted studies on composition of this residue (Table 6). The residue contained on dry weight basis about 9 per cent protein, 4 per cent fat, 8 per cent crude fibre, 1.0 per cent pectin and was also rich in ascorbic acid and minerals. They have suggested the residue to be utilised for the recovery of low methoxyl pectin as its jelly grade was found to be poor or as cattle feed after drying.

TABLE 6. **Composition of Cashew Apple Residue**

		Dry weight basis
1.	Total ash %	1.8
2.	Total pectin as Ca pectinate %	10.7
3.	Total tannins %	5.0
4.	Proteins (N x 6.25)%	9.0
5.	Ether extractives %	4.4
6.	Crude fibre %	8.5
7.	Calcium mg %	20.5
8.	Iron mg %	35.6
9.	Phosphorus mg %	152.1

Suggestions for further work : Of the several products considered cashew apple juice, blended cashew apple juice, cashew apple candy and cashew apple juice concentrate appear to have the potential to develop into commercial products provided good quality products could be produced by adopting new and improved techniques of processing. To achieve this objective further intensive work has been suggested on the following aspects.

1. Improved methods of collection of fruits.
2. Optimum maturity for harvesting in relation to both nut and fruit quality.
3. Production of better quality juice using enzyme clarification method.
4. Development of better quality blended juice.
5. Production of cashew apple candy making use of continuous preserve making unit.
6. Preparation of cashew apple juice concentrate using latest evaporators.

7. Possible use of concentrate in aerated, baking and confectionary industry.

8. Production of flavour concentrate by aroma recovery and adding back to various formulated products.

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Scope for Development of Alcoholic Beverage from Cashew Apple

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Abstract

Cashew apple juice contains sugar, protein, acid and large amounts of vitamin C. The juice also contains an astringent principle, polyphenolic in nature. The juice though one of the richest sources of vitamin C is not acceptable as a soft drink on account of its high astringency. The juice is a good media for alcoholic fermentation, as it contains all the nutrients for growth of yeast. The cashew wine contains about 4 per cent alcohol but has astringency. Brandy – distillate of wine – does not have the astringency but possesses the exotic flavour of cashew apple. Studies conducted at Central Food Technological Research Institute, Mysore have shown that the cashew apple hitherto considered as a waste can be profitably utilised in preparing alcoholic beverage.

Production of cashew apple in India: Out of an estimated yield of 8.4 lakh tons of cashew apple in India, Kerala tops the list with nearly 6,00,000 tons, followed by Karnataka (75,000), Andhra Pradesh (60,000), Tamil Nadu (50,000), Goa (30,000) and Maharashtra (20,000).

All through the years, the importance of cashew has been for its tasty nuts, which are favoured round the world. The processing of the nuts is on a big scale in the country but in the small scale sector. Apart from the nut, the next important product from cashew is the cashewnut shell oil, which is commercially exploited.

Cashew apple is a modified peduncle or the fruit stalk. It has all the characters of the fruit both in appearance and content. At present, cashew apple is utilised to a limited extent. Thus, large part of the produce is thrown away without being put to any use. The object of this paper is to focus the attention to this neglected front. In the coming years, with increased production of cashewnuts, one can expect a corresponding increase of cashew apple which is going to be a big challenge to technologists. It is necessary that the technology for utilisation of this valuable raw material is geared up to meet the situation.

Chemical composition of cashew apple juice: Cashew apple juice contains 10.7 per cent total reducing sugar with 0.3 per cent acid, pH of 4.0 and protein 0.3 per cent. Total reducing sugar consists of glucose and fructose (Table 1). The juice contains adequate amounts of nutrients and the pH is optimum for the growth of yeast.

TABLE 1. **Physico-Chemical Characteristics of Cashew Apple Juice**

S. No.	*Physico-chemical characteristics*	*Maximum*	*Minimum*	*Average*
1.	Fruit weight, (g)	140.7	13.0	37.9
2.	Juice, %	84.3	46.9	67.1
3.	Brix	18.3	7.2	12.4
4.	Acidity, % (as malic acid)	0.7	0.1	0.3
5.	pH	4.6	3.7	4.0
6.	True ascorbic acid (mg/100 ml)	265.5	17.2	105.4
7.	Total reducing sugars, %	17.7	5.3	10.7
8.	Glucose, %	11.6	5.1	7.9
9.	Fructose, %	6.5	0.2	2.6
10.	True tannin, % (as tannic acid)	0.7	0.0	0.2
11.	Protein, N x 6.25	0.3	0.2	0.3

Source: Sondhi, S.P. 1962. "Studies on physico-chemical and technological aspects of cashew apple – some observations". Thesis submitted for award for associateship, CFTRI, Mysore.

Present use of the juice: The juice is expressed by trampling and collected in a stone tank. The juice is filled into earthen pots and kept aside or buried in the earth. The fermentation is initiated by the mixed flora consisting of yeast, bacteria and moulds. After a few days, the brew is distilled using a copper tube over which cold water is manually poured and the distillate is collected in a copper or earthen pot. This distillate contains about 18–20 per cent alcohol. Fresh cashew juice in the ratio of 1:3 is added and then distilled. The distillate now contains around 38 – 40 per cent alcohol and is called feni. This is a traditional alcoholic liquor of Goa.

In this process, the efficiency of operation from expression of juice to distillation is low. Further fermentations are left to the vagaries of contaminating organisms. In a mixed fermentation there is strong competition between the different types. The undesirable organisms utilise the sugars to produce products other than alcohol and flavour at the cost of yeast which can produce these products in much greater quantities than them. This results in poor yield of alcohol. Since the fermentations are not controlled, the end-products become of varying in quantity. Thus it would be difficult to get consistently uniform quality product. It is possible to improve the existing methods of extraction, collection of juice, controlled fermentation and distillation using mechanical crushers and presses, clean fermentation tanks, pure strain of yeast and small distillation assemblies. In this way, a big improvement at the cottage level can be attempted.

Composition of fermented cashew apple juice: The composition of cashew apple wine under controlled conditions of fermentation is given in table 2. This has increased not only the operational efficiency but also the yield of alcohol at the wine. The wine had retained the characteristic exotic flavour of cashew apple. Preparation of brandy from the wine was the next logical step.

TABLE 2. **Composition of Fermented Cashew Apple Juice**

S. No.	*Constituent*	
1.	Brix	3.00
2.	pH	4.00
3.	Acidity, % (as malic acid)	0.63
4.	Volatile acid, % (as acetic acid)	0.03
5.	Ethyl alcohol, % W/V	5.51
6.	Tannin, % mg (as tannic acid)	145.00
7.	Total reducing sugars, %	0.38
8.	Esters expressed as ethyl acetate, mg %	0.023
9.	Aldehydes expressed as acetaldehyde, mg %	0.002
10.	Higher alcohol, gm/100 litres of absolute alcohol	16.40
11.	Furfural, gm/100 litres of absolute alcohol	1.25
12.	Copper	Nil

Source: V.M. Patwardhan. 1970. A Dissertation on "Cashew Apple Fruit" and an investigation on "Fermented Cashew Apple Beverage". Thesis submitted for M.Sc. (Food Tech.), Mysore University.

Composition of the brandy: In the production of brandy, the distillate is usually collected at 60 per cent alcohol. This is done as maturation of distilled alcoholic beverage is done at this concentration. The concentration of alcohol is later adjusted to required level. The other constituents are well within the levels, specified by I.S.I. for fruit brandys (Table 3).

TABLE 3. **Chemical Composition of Cashew Apple Brandy (g/100 l of absolute alcohol)**

Ethyl alcohol	42.85
Volatile acids as acetic acid	12.28
Esters as ethyl acetate	55.97
Aldehyde as acetaldehyde	18.28
Higher alcohol	149.70
Furfural	3.22
Copper	1.04

Yield of wine from large scale trials: In this study, the basket press has been used and the yields of wine are 58 per cent (I) and 66 per cent (II). The yield of alcohol based on the weight of fruit is about 2.5 per cent w/w. In terms of volume of alcohol it will be 3.17 per cent (Table 4).

TABLE 4. **Yield of Wine from Large Scale Trials**

		Batches	
		I	*II*
1.	Weight of cashew apple (kg)	835	735
2.	Volume of wine (I)	486	496
3.	Weight of pulp (kg)	190	203
4.	% Yield of wine (V/W)	58.3	66.3
5.	% Yield of alcohol	2.49	2.52

Source: M.S. Subba Rao, 1973. "Wine Technology" Proc. Symposium 'Alcoholic Beverage Industries, Present Status and Future Prospects', Association of Food Scientists and Technologists (India), Mysore.

One ton of fruit on this basis yields 31.7 litres of absolute alcohol. One litre of absolute alcohol (100 %) on dilution to brandy strength of 42.85% alcohol yields 2.33 litres of brandy. Therefore, 31.7 litres of alcohol yields 73.86 litres of brandy.

The country, according to estimates, produced 8.4 lakh tons of cashew apple in 1975–76 as already indicated. Assuming that the entire production of fruits in Goa and in some other regions are utilised for fermentation which totals upto 40,000 tons, even then the balance of nearly 8 lakh tons of valuable raw material is at present wasted. It is unrealistic to expect that all these fruits can be utilised. Even if half this available fruits are used for production of alcoholic beverage the volume of cashew brandy that can be produced will be 29.5 lakh litres of brandy. There is a vast potential for development in this area.

Discussion

D.C. Russell : Cashew apples are allowed to drop from the tree and when bruised they will start fermenting. Cashew apples do not travel well. If importance were attached to the apple, the apple might be picked from the tree before the nut is matured thus destroying the quality of the kernel. Do you think the apple should be preserved at the expense of the kernel?

M.S. Subba Rao : No. The collection of the apples should not be at the cost of kernel. Transportation to the processing centre should be within 3 – 4 hrs. after harvest.

L.D.G. Coward: The problems associated with the harvesting of cashew apples for processing can be over-come efficiently if the nuts themselves are also to be harvested and processed.

A.S.L. Tirimanna: Were any experiments carried out to increase the *body* of the cashew wine by the addition of the hydro-colloid sodium alginate which is manufactured in India?

M.S. Subba Rao: No experiments have been carried out to increase the *body* of cashew wine.

Physico-Chemical Qualities of Cashew Apples of High Yielding Types

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Abstract

Physico-chemical characters of cashew apples of sixteen high yielding types were studied during the period 1977–78 with a veiw to identifying types producing superior quality apples. The type K 10–2 ranked first in respect of the mean weight, length, diameter, length/diameter ratio and juice content of apples. In type M 6/1 the highest percentage of TSS, specific gravity and sugar content were recorded, K 27–1 was superior in ascorbic acid content. Lowest tannin content was found in BLA-40 and the highest protein in M 10/4. Vengurla 37–3 stood first in ether extractives and BLA–273 in crude fibre content. Apples of BLA–1 and Ansur 1–27 had the highest carbohydrate. Considerable variation existed between the seedling progenies of the same type with respect to almost all characters studied.

Introduction

Cashew apple which is the swollen pedicle of the fruit, is a rich source of the nutritious juice. It is practically wasted in our country due to the presence of tannins and some other astringent principles. It is estimated that about 12 lakh tons of cashew apples are annually produced in our country out of which nearly 85 per cent is unutilised.

A number of workers, Jain (1951), Singh and Mathur (1953), Ventura and Hollanda (1958), Sastri et al. (1962) and Periera and Bornalho (1966) have reported the chemical composition of cashew apple juice and indicated the possibility of utilising it as soft drink or fermented liquor.

But none of the earlier workers eventhough indicated significant differences in the physico-chemical composition of cashew apples, collected from different trees, have approached this problem from a varietal point of view. Now, a number of high yielding types have been identified; but the apple characters were not taken into account in the evolution of these types, as it was not utilised. The present studies were therefore undertaken to find out the apple qualities of the different types under yield trials so that apples suitable for different products can be identified and fully utilised.

Materials and Methods

Apples for the study were collected from the four year old seedling progenies of sixteen promising types assembled at the All India Co-ordinated Cashew Improvement Project experiments at Vellanikkara. Representative samples of ten fully ripe apples were collected from each tree to determine the juice content and chemical composition. To compare the varieties three trees from each replication were selected randomly. Variation within a type was studied by collecting samples from all the twenty seven trees in a type. Physico-chemical characters of apples like colour shape weight length, diameter, percentage juice, total soluble solids, sugar, acidity, asorbic acid, tannin, specific gravity of juice, protein, ether extractives, carbohydrate, crude fibre, calcium, phosphorous and iron were determined as per the standard methods by A.O.A.C. (1970).

Results and Discussion

The present investigation showed considerable variation in the morphological characters like colour and shape of apples of different types and between progenies of the same type. The percentage of seedling progenies of the different types classified on the basis of colour and shape are presented in table 1.

It was observed that the colour of apples of different types can be grouped under three categories, viz., red, yellow and mixed shades of these two. Only BLA–1 produced uniformly single coloured (yellow) apples.

The shape of apples of different types came under four groups namely conical, cylindrical, pyriform and rhomboid. When both colour and shape are considered the progenies of K 27–1 showed maximum uniformity.

Average weight, length, diameter, length/diameter ratio and juice recovery are presented in table 2.

In respect of average weight, length, diameter and percentage juice recovery, the type K 10–2 ranked first. This type produced the largest apples of 75.4 g weight 94 cm length and 5.06 cm diameter. The smallest apples were produced by BLA 256–1, the mean weight being only 29.2 g. The maximum length/diameter ratio of 1.86 was recorded in the type K 10–2 followed by K 27–1. Considering the uniformity in colour and shape, the best type was K 27–1. The juice recovery of apples of different types varied from 44.9 to 64 per cent. K 10–2 gave highest juice recovery of 64 per cent followed by 'Sawanthwadi' which yielded 62.5 per cent juice. It will be economic to select apples of these types for the extraction of juice.

TABLE 1. **Variability in Colour and Shape of Apple in Sixteen Cashew Varieties**

Varieties	*Colour Apples*			*Shapes of Apple*			
	Yellow	*Red*	*Mixed shade*	*Conical*	*Cylin-drical*	*Pyri-form*	*Rhom-boid*
Ansur 1–27	55.8*	27.5	16.7	33.33	44.54	0.00	22.22
Vengurla 36–3	7.7	53.8	38.5	55.60	11.10	11.10	22.22
Sawantwadi	0.0	60.0	40.0	11.11	44.44	44.44	0.00
Vengurla 37–3	0.0	86.4	13.6	22.22	66.66	0.00	11.11
BLA–1	100.0	0.0	0.0	11.11	44.44	44.44	0.00
BLA–40	84.2	0.0	15.8	33.33	22.22	44.44	0.00
BLA–56	90.0	5.0	5.0	22.22	44.44	33.33	0.00
BLA–273	76.9	15.4	7.7	0.00	22.22	44.40	33.33
M 10/4	87.5	4.2	8.3	33.33	33.33	22.22	11.11
M 6/1	50.0	18.2	31.8	11.11	11.11	0.00	77.78
K 27–1	88.2	0.0	11.8	11.11	77.78	0.00	11.11
M 76–1	69.6	8.7	21.7	33.33	22.22	11.11	33.33
H 4–7	39.1	13.0	47.9	44.44	11.11	22.22	22.22
K 10–2	30.8	0.0	69.2	66.70	33.30	0.00	0.00
BLA 139–1	79.0	0.0	21.0	66.70	22.20	0.00	11.10
BLA 256–1	83.3	0.0	16.7	22.22	22.22	33.33	22.22

*Percentage

TABLE 2. **Average Weight, Length, Diameter, Length/Diameter Ratio and Juice Recovery of Apples in Sixteen Cashew Varieties.**

Varieties	*Average weight (g)*	*Length (cm)*	*Diameter (cm)*	*Length/ Diameter ratio*	*Juice recovery (%)*
Ansur 1–27	47.9	6.3	4.75	1.33	57.4
Vengurla 36–3	40.8	6.1	4.90	1.24	57.6
Sawantwadi	50.2	7.3	5.13	1.42	62.5
Vengurla 37–3	32.3	5.8	4.08	1.42	48.5
BLA–1	39.0	5.7	4.81	1.19	60.5
BLA–40	41.1	6.7	4.59	1.46	55.5
BLA–56	36.2	6.2	4.36	1.42	53.4
BLA–273	39.7	6.2	4.87	1.27	54.1
M 10/4	40.4	6.2	4.75	1.31	44.9
M 6/1	43.3	6.9	4.59	1.50	60.5
K 27–1	45.3	7.1	4.65	1.53	53.2
M 76–1	32.3	5.6	4.30	1.30	59.2
H – 4–7	39.4	6.3	4.65	1.35	61.5
K 10–2	75.4	9.4	5.06	1.86	64.0
BLA 139–1	31.9	6.0	4.24	1.42	58.6
BLA 256–1	29.2	4.9	4.39	1.12	58.2
Significance	**	**	*	..	**
C.D. (P = 0.05)	9.92	0.94	0.59	..	5.13

* Significant at 5% level. ** Significant at 1% level.

The highest T. S. S. of 14.67 per cent and specific gravity 1.07 was recorded in M 6/1 (Table 3). The highest quantity of sugar (as reducing) was recorded in the apples of the type M 6/1 (13.37 per cent) followed by

TABLE 3. **Chemical Composition of Cashew Apple Juice in Sixteen Varieties**

Varieties	*T.S.S.* %	*Specific gravity*	*Reducing sugars* %	*Acidity as malic* %	*Ascorbic acid mg/100g.*	*Tannin %*	
						Total	*True*
Ansur 1–27	12.67	1.058	10.93	0.38	261.33	0.47	0.27
Vengurla 36–3	13.44	1.057	12.91	0.46	239.30	0.52	0.25
Sawantwadi	12.67	1.061	11.70	0.39	242.87	0.49	0.25
Vengurla 37–3	11.06	1.047	9.99	0.50	289.48	0.74	0.36
BLA–1	13.22	1.061	11.93	0.47	253.06	0.47	0.24
BLA–40	12.72	1.053	11.16	0.45	308.68	0.33	0.20
BLA–56	13.56	1.056	11.74	0.42	238.47	0.51	0.28
BLA–273	12.61	1.053	11.09	0.58	247.50	0.56	0.29
M 10/4	11.67	1.051	10.56	0.51	283.84	0.58	0.29
M 6/1	14.67	1.066	13.37	0.46	241.81	0.45	0.25
K 27–1	12.06	1.053	10.96	0.40	321.16	0.56	0.25
M 76–1	12.83	1.056	11.73	0.36	224.52	0.49	0.27
H 4–7	13.33	1.057	11.92	0.37	243.30	0.37	0.22
K 10-2	12.89	1.060	11.17	0.45	230.28	0.49	0.28
BLA 139–1	11.89	1.053	10.89	0.44	251.30	0.46	0.31
BLA 256–1	11.56	1.049	9.88	0.44	220.84	0.39	0.27
Significance	*	**	**	N.S.	*	**	**
C.D. (P = 05)	1.57	0.0078	1.58	..	57.35	0.11	0.064

* Significant at 5% level. ** Significant at 1% level N.S. Not Significant.

Vengurla 36–3 in which the sugar was 12.91 per cent. The entire quantity of sugars present in the juice was reducing sugars. Maximum sugar content and an acidity percentage of 0.39 to 0.42 as malic in cashew apple is desirable for the juice products like cashew apple juice, clarified juice, cloudy juice and caskola. Accordingly apples of M 6/1, Vengurla 36–3 and BLA–56 were found to be better for the preparation of juice products. In ascorbic acid content, K 27–1 topped the list with 321.16 mg/100 g juice followed by BLA–40 which had 308.68 mg/100 g. Higher amounts of ascorbic acid in cashew apple juice is considered as a desirable character.

TABLE 4. **Chemical Composition of Apples in Sixteen Cashew Varieties£**

Varieties	*Protein* %	*Ether extractives* %	*Carbohydrate* %	*Crude fibre* %	*Calcium* %	*Phosphorus* %	*Iron* %
Ansur	0.50	0.52	10.62	0.80	0.006	0.020	0.0011
Vengurla 36–3	0.54	0.69	10.25	0.75	0.014	0.025	0.0013
Sawantwadi	0.72	0.55	8.13	0.69	0.013	0.026	0.0015
Vengurla 37–3	0.72	0.76	9.43	0.78	0.008	0.016	0.0010
BLA–1	0.77	0.51	11.53	0.62	0.012	0.017	0.0010
BLA–40	0.81	0.39	9.77	0.88	0.015	0.027	0.0016
BLA–56	0.71	0.40	9.98	0.71	0.011	0.021	0.0012
BLA–273	0.72	0.55	10.33	0.91	0.112	0.023	0.0013
M 10/4	0.92	0.57	10.22	0.78	0.010	0.019	0.0013
M 6/1	0.46	0.49	10.16	0.75	0.008	0.014	0.0009
K 27–1	0.65	0.55	10.21	0.67	0.012	0.022	0.0015
M 76–1	0.74	0.52	9.96	0.71	0.008	0.017	0.0012
H 4–7	0.67	0.44	10.60	0.75	0.009	0.018	0.0012
K 10–2	0.48	0.50	9.72	0.70	0.011	0.012	0.0008
BLA 139–1	0.81	0.44	9.50	0.72	0.005	0.012	0.0008
BLA 256–1	0.42	0.41	8.91	0.77	0.008	0.016	0.0011
Significance	**	**	..	**	**	**	**
C.D. (P = 0.05)	0.084	0.075	..	0.059	0.0022	0.0044	0.00029

£ Mean values expressed on F.W.B.

N.S. Not significant ** Significant 1% level.

Tannin which is responsible for the astringent taste was minimum in BLA–40 (0.33%) and the highest in Vengurla 37–3 (0.74%). It was reported that the total tannin can be effectively removed by steam and chemical treatments. Sastry et al. (1962) reported that steam and chemical treatments adversely affected the other nutrients contents of the apple. So selecting BLA–40 having a tannin content of 0.33%, H 4–7 and BLA 256–1 (0.39%) may prove to be quite suitable for industrial exploitation.

The type M10/4 had the highest protein content (0.92%) followed by BLA–40 (0.81%) (Table 4). Vengurla 37–3 (0.76%) and Vengurla 36–3 (0–69%) had higher ether extractives. BLA–273 (0.91 %) produced apples having highest crude fibre content followed by BLA–40 with a crude fibre content of 0.88 per cent. Maximum carbohydrate content was obtained in BLA–1 (11.53 %) followed by Ansur 1–27 (10.62 %).

Considerable variability in chemical and morphological characters of apple between seedling progenies of the same type was observed.

Type K 10–2 exhibited uniformity with regard to total soluble solids, sugar content and iron content. Apples of seedling progenies of Vengurla 36–3 showed least variation in average weight. BLA 256–1 showed maximum uniformity in percentage juice recovery, total tannin and crude fibre. Minimum variability in acidity was recorded by the seedling progenies of Vengurla 37–3 whereas BLA–273 showed maximum uniformity in ascorbic acid content of apple juice. Least variability was recorded in protein content of M 10/4 ether extractives and phosphorus in H 4–7 and calcium in K 27–1.

The results of these studies indicate that there is considerable scope for selection of type suitable for different products that can be made from cashew apple. With the development of effective methods for cashew apple utilisation, the quality aspects of cashew apples will be highly important.

Acknowledgement

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Discussion

P.M. Kumaran: Is there any correlation between colour of the apple and sugar content?

Vilasa Chandran: Singh and Mathur (1953) and Mortan (1970) have reported that yellow apples were generally of superior quality as indicated by higher TSS and sugar content and lower acidity compared to red apples. But our results do not agree with it. Type M 6/1 which produced 50 per cent progenies having yellow apples has a TSS of 14.67, sugar 13.37 percent and acidity of 0.46 per cent as compared to BLA – 1 in which 100 per cent trees produced yellow apple progenies had a TSS of 13.22 sugar 11.93 and acidity 0.47 per cent. So it appears that the quality of cashew apple is essentially a varietal character which is not determined by its colour. However, higher TSS and sugars were recorded by the progenies producing yellow apples than those producing red apples of the same type.

Cashew Apple Liquor Industry in Goa

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Abstract

About 20 lakh tons of cashew apples are produced in India annually which are at present being just wasted, except in Goa where it is utilized for the preparation of 'feni'. Sporadic attempts to promote its economic utilization has proved infruitious in other states. The utilization of cashew apples for the manufacture of liquor as a cottage industry in Goa has been described in detail. Further, the possibility of manufacturing industrial alcohol is dealt in brief.

The cashew apple is the swollen peduncle supporting the cashewnut. The apple is soft and juicy when ripe and is acidic and highly astringent. The natural acidity of the juice can be reduced by the addition of 0.25 per cent of sodium chloride. The juice content and the composition of the apples is highly variable. The apple is a rich source of vitamin C (260 mg/100 g) and gives about 35 calories. It contains 9 per cent sugar (mostly reducing sugars), 0.5 per cent tannic acid, 11.6 per cent carbohydrate, 0.2 per cent protein, 0.2 per cent mineral matter, 0.1 per cent fat, 0.09 per cent carotene, 0.01 per cent Ca and 0.01 per cent P.

It is estimated that about 20 lakh tons of cashew apple are produced in India annually, along with 1.66 lakh tons of raw cashewnut from 4.1 lakh ha area (1974–75 estimate). This huge quantity of cashew apple produced is being mostly thrown away except in Goa where it is utilized for the manufacture of 'feni'.

In Goa, approximately 50,000 tons of cashew apple, 70 per cent of the total production (72,500 tons) are utilized in liquor industry which is running on cottage industry basis. Out of total income from cashew production, 35 per cent represents income from apples. Thus, the cashew liquor industry in Goa provides gainful employment to more than 10,000 families at present for a period of three months (March to May). Cashew, being a seasonal crop the *caju* apple distillation process cannot be done throughout the year. This employment opportunity to the cashew growers of Goa gives a good incentive at the appropriate time, when the main rice crop is harvested.

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Cashew apples perish within a short time and hence must be processed soon after collection. Since the juice does not keep well longer, it is normally fermented and made into liquor which retains the flavour of fresh juice.

The cashew apple must be collected at the right moment squeezed in the right manner, left to ferment at the right temperature and then distilled to give *caju* 'feni'. It is believed in Goa from the earliest times that the distillation of liquor from cashew apple is also for medicinal purposes for the infants to old-aged.

	Test	*I.S.I. Limits for*		*Quality of cashew**	
		Whisky	*Rum*	*Liquor*	*Feni*
1.	Total solids (% wt/vol.)	0.2 (max.)	..	0.057	0.009
2.	Total ash (% wt/vol.)	0.02 (max).	..	0.017	0.009
3.	Volatile acid as acetic acid (g/100 l absol. alcohol)	20 – 100 g	100 g (max.)	9.93 g	15.2 g
4.	Esters as ethyl acetate (g/100 l a absol. alcohol)	8 g (min.)	10 g (min.)	140.8 g	97.3 g
5.	Higher alcohol as amyl alcohol (g/100 l absol. alcohol)	30 – 300 g	300 g (max.)	115 g	78.5 g
6.	Aldehydes as acetaldehyde (g/100 l absol. alcohol)	45 g (max.)	45 g (max.)	23.9 g	24.8 g
7.	Furfural (g/100 l absol. alcohol)	12 g	12 g (max.)	Nil	Nil
8.	Copper as Cu (ppm)	10 (max.)	10 (max.)	3	3
9.	Alcohol content	25° U.P.	25° U.P.	24.3° U.P.	24° U.P.

*Samples referred comply with I.S.I. specifications for foreign liquors – Whisky/Rum.

Cashew liquor unlike the Indian made foreign liquor (I.M.F.L.) viz. Brandy, Whisky, Rum, Gin etc., are not made by blending of spirits but distilled exclusively from the pure juice of cashew apples without addition of any extraneous matter.

It has been proved to be a foreign exchange earner in this territory. Since the export oriented liquor is not prohibited, it can be produced by the distillary as per I.S.I. specifications (see page 174) for Whisky (I.M.F.L.) to enter the world market as an export commodity.

Cashew 'feni' is manufactured in Goa for the past four centuries under crude and unhygenic country methods of distilling. These distillaries, known as 'Bhatti' comprise of a copper cauldron 'Bhan', a clay pot 'Lawni' (condenser), a pipe (specially of bamboo) and an open hearth. The copper cauldron is fixed to the open hearth leaning towards the opposite direction of the mouth of the hearth. This copper cauldron has a small hole at the upper half in which a 60 cm long pipe is fixed properly. The other point of the pipe is fixed to the mouth of the clay pot. The clay pot is erected above ground on a stand at a distance, to avoid heat from the hearth. The pipe acts as a transformer of the vapour from the copper cauldron to the clay pot which acts as the condenser. In Goa, about 1617 country stills are established covering almost all the cashew plots.

Juice Extraction: The apples after collection are pooled in a specially prepared depression (locally known as 'Kolmbi') which is prepared by carving stones. The apples are crushed by legs and the juice extracted. The juice flows out and collected in an earthen vessel or in a tin.

At the first crushing by legs, the juice does not squeeze out completely and so the residue (pulp) is bundled (locally known as 'Nudi') by tying with strong creepers and kept under heavy stones to squeeze the remaining juice. In this process, about 3.5 kg cashew apple is required to get 1 litre juice; but through machine extraction, 2 kg apple can give 1 litre juice.

The single roller device recently designed, is somewhat improved over the present method, but the process is slow and the extraction of juice is also not perfect, but there is a more modernised and mechanised process where the performance is satisfactory.

In an improved juice expeller manufactured in Phillippines, the apples are fed to a small hopper and crushed between a wooden roller and a concave wooden board. The juice flows through the perforations of the concave board and the pulp comes out of the retracting wall, the pressure of which is regulated by a compression spring. This device is capable of crushing an average of 140 kg of apple per hour and the juice extraction efficiency to the extent of 70 per cent is achieved. In Goa also, expellers of this type have been introduced very recently in modern distillaries to improve the extraction upto 70 per cent.

Varieties of Cashew Liquor: The extracted juice is kept for 2 to 3 days to get it fermented to improve liquor quality. The fermentation is verified on the basis of formation of the film floating over the juice. Fermentation efficiency to the extent of 98% is possible if the values of controlling factors like type and kind of yeast, temperature, aeration of juice etc. are kept to the optimum.

From 50 litre fermented juice, 35 litres of uraq is distilled which contains alcohol. The feni is obtained by distilling uraq, mixed with fermented juice at 1:2 ratio, which is powerful form of cashew liquor. A mixture of 30 litres of uraq and 60 litres of juice produce 15 litres of feni which contains 75 per cent of alcohol. To get a litre of uraq, 12 kg of cashew apple and for a litre of feni 30 kg cashew apples are required. For distilling 15 litres of liquor, 3 to 5 hours are required. The cost of manufacturing uraq and feni (15 litres) are estimated to be Rs. 70 and Rs. 140 respectively. In 1975 about 70,000 tonnes of cashew apples produced 11 lakh litres of cashew liquor in Goa, bringing Rs. 17 lakh revenue as excise duty. Industrial spirit and absolute alcohol can also be distilled out of fermented juice.

Acknowledgement

The authors are thankful to the Community Canning Centre (Govt. of India), Panaji for rendering necessary help in preparing different cashew apple products exhibited during the symposium.

On Nutritional Value of the Protein in the Cashew Seed

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Abstract

Protein and amino acid contents in cashew whole kernel flour and in by products obtained from different African sources, viz. Dahomey, Madagascar, Mozambique, Tanzania were worked out. In addition to calculating the protein score and chemical score, the biological evaluation tests were also carried out. The protein efficiency ratio gave similar results for whole cashew kernels and cashew by-products. Remarkable difference in sulphate amino acid contents was found, in particular, the methionine content being lower in Madagascar kernels. The protein score was found to be higher than soy proteins subjected to heat treatment. The very high food value of the cashew-nut proteins was found to be the highest of the vegetable kingdom.

Some of the wide range of products obtained from cashew either directly or indirectly have assumed considerable economic importance. The research was directed at evaluating the flour obtained from whole kernels and from the by-products supplied by Oltremare. The work was mainly confined to defining the food value of the protein content in whole kernels derived from different African sources: Dahomey, Madagascar, Mozambique, Tanzania and to the evaluation of by-products.

Evaluation of the protein content in the whole cashew kernel : Best quality whole kernels without tegument were ground and defatted to obtain a flour with crude lipids ranging from 1 to 2 per cent was utilized for this experiment (Table 1 and 2).

TABLE 1. **Content of Crude Food Principles Found in Defatted Cashew Extraction Meal (indicated in % of dry matter)**

Analytical details	*Dahomey*	*Madagascar*	*Mozambique*	*Tanzania*
Moisture	6.22	6.72	7.72	7.35
Crude Protein	41.99	37.57	43.04	36.37
Crude Lipids	2.04	1.58	2.40	1.68
Crude Fibre	1.48	1.52	1.43	1.62
Ash	5.22	4.82	5.16	4.42
Nitrogen free Extracts	49.27	54.51	47.97	55.91

TABLE 2. **Percentages of Various Amino Acids Found in Cashew Extraction Meal from Different Places (in % of the protein).**

Amino Acids	*Dahomey*	*Madagascar*	*Mozambique*	*Tanzania*
Lysine	5.30	5.33	4.85	4.63
Histidine	2.39	2.34	2.13	2.21
Arginine	11.37	10.38	10.89	10.71
Aspartic Acid	9.26	9.37	8.79	8.84
Threonine	3.74	3.97	3.79	3.16
Serine	5.17	4.95	5.17	4.84
Glutamic Acid	23.96	22.93	22.35	23.66
Proline	2.19	3.58	2.69	3.55
Glycine	5.66	4.75	4.37	4.18
Alanine	4.75	4.13	3.72	3.71
Valine	8.04	6.56	6.43	5.89
Methionine	2.22	2.65	1.98	1.56
Isoleucine	4.93	4.66	4.48	4.46
Leucine	7.45	7.29	6.70	7.54
Tyrosine	2.90	2.85	2.84	2.26
Phenylalanine	4.70	4.80	4.58	4.34
Cystine	2.45	1.70	1.55	1.16
Tryptophan	1.53	1.28	1.18	1.37

From the analytical value the "protein score" pertinent to some animal species, was tested, biologically, on small laboratory animals following the usual methodology.

The results obtained are given in tables 3 and 4.

TABLE 3. **"Protein Score" and "Chemical Score"**

	Dahomey	*Madagascar*	*Mozambique*	*Tanzania*
"Protein score" as regards the protein needs of:				
Rats	100	100	100	91 (a)
Chickens	100	95 (b)	88 (a)	68 (a)
Pigs	100	100	100	83 (a)
"Chemical Score"	67 (c)	68 (c)	62 (c)	59 (c)

a = deficient in sulphured amino acids. b = deficient in glycine. c = deficient in lysine

TABLE 4. **Results of the Biological Test**

	Protein Efficiency Ratio (P.E.R.)	*Protein Efficiency Ratio (P.E.R.) % of casein*
Casein Test	2.87	100
Cashew extraction meal from Dahomey	3.01	105
Cashew extraction meal from Madagascar	3.25	113
Cashew extraction meal from Mozambique	2.88	100
Cashew extraction meal from Tanzania	3.25	113

From the examination of the data shown above it is possible to indicate that:

(i) the content of crude protein shows variations, which cannot be disregarded, ranging from a minimum of 36.37 (Tanzania) to a maximum of 43.04 per cent (Mozambique) with a difference of approximately 18 per cent. The proportions of nitrogen free extracts were negatively correlated with crude protein.

(ii) Remarkable differences were found in the composition of amino acids, especially the sulphured amino acids, and in particular methionine (from a maximum of 2.65% protein found in the sample from Madagascar to a minimum of 1.56% in the sample from Tanzania).

(iii) The "protein score" is very high – except for the flour of Tanzania kernels which is lacking in sulphured amino acids – and is close to the ideal proteins for the species taken into consideration, and higher than soy proteins subjected to heat treatment, proteins of which are the noblest of the plant kingdom.

(iv) The "chemical score" is not high, the average value varying from 68 for the sample from Madagascar to 59 for Tanzania.

(v) The biological test carried out on growing young rats has pointed out what is already indicated in the "protein score". Comparing the protein efficiency ratio (P.E.R.) from the feeding tests carried out with flour extracted from kernels coming from different places, no significant difference was found among the different groups and in comparison with the group fed with a standard mixture ideal for feeding rats.

Evaluation of the protein content in cashew by-products: The various products obtained from industrial processing of cashew kernels viz. kernel without tegument (A); fragments with tegument residues (B); germ of the kernel (C) were utilized for the study.

These products were defatted as previously described and submitted to chemical analysis and the results are summarized in tables 5 and 6.

TABLE 5. **Composition of Crude Food Principles of Some Flours Extracted from Products Derived from the Industrial Processing of Cashew (in percentage of dry matter)**

Analytical details	*A*	*B*	*C*
Moisture	7.31	8.01	7.14
Crude Protein	36.36	37.67	42.47
Crude Lipids	1.38	1.95	2.56
Crude Fibre	1.47	2.96	2.36
Ash	4.57	4.93	6.52
Nitrogen-free-Extracts	49.71	52.49	46.09

A — Kernel without tegument; B — fragments with tegument residues;
C — germ of kernel.

TABLE 6. **Composition of Amino Acids (in % of proteins)**

Amino Acids	*A*	*B*	*C*
Lysine	5.04	5.00	4.43
Histidine	2.48	2.30	2.24
Arginine	11.01	10.44	13.77
Aspartic Acid	9.91	9.02	9.49
Threonine	3.22	3.40	4.01
Serine	5.36	4.80	4.18
Glutamic Acid	24.48	21.05	16.95
Proline	3.94	2.50	3.78
Glycine	4.31	4.02	4.58
Alanine	3.98	3.15	4.43
Valine	5.94	5.70	5.38
Methionine	1.67	1.72	1.50
Isoleucine	4.72	4.40	3.97
Leucine	8.14	6.94	6.76
Tyrosine	2.51	2.74	2.27
Phenylalanine	4.45	4.65	4.39
Cystine	1.18	2.05	2.74
Tryptophan	1.40	1.44	1.03

A — kernel without tegument; B — fragments with tegument residues;
C — germ of the kernel.

For these products the "protein" and "chemical scores" were calculated and biological tests were carried out as in the first series of experiments.

The pertinent results are shown in tables 7 and 8.

TABLE 7. **Protein Score and Chemical Score of the Flours Examined**

	A	*B*	*C*
"Protein score" as regards the needs of:			
Rats	95 (a)	100	98 (b)
Chickens	92 (c)	97 (c)	89 (b)
Pigs	91 (a)	100	100
"Chemical score"	69 (a)	69 (a)	69 (a)

a — deficient in sulphured amino acids. b — deficient in lysine
c — deficient in threonine

TABLE 8. **Results of the Biological Test**

	Protein Efficiency Ratio (P.E.R.)	*Protein Efficiency Ratio (P.E.R.) % of casein*
Casein Test	2.87	100
extraction meal A	2.80	97
extraction meal B	2.51	87
extraction meal C	2.92	102

From this second phase of experiments it is possible to indicate that:

(i) the composition in crude food principles of the flour extracted from the products deriving from industrial processing, shows a considerable difference in the fibre content between the sample of flour extracted from fragments rich in teguments and the flour extracted from kernels; the flour extracted from the germ shows a higher content of crude protein fiber and ash;

(ii) The amino acids composition expressed as a summation of the essential amino acids shows a similar value for the flour extracted from kernels and from fragments (45.82 and 45.08) while flour extracted from the germ has a higher value (41.11) which is basically due a better endowment of arginine, threonine and cystine;

(iii) Values for the "protein score" were very high for all extracted flours;

(iv) The biological evaluation gives value of protein efficiency ratio similar to those obtained with the feeding test with a basis of casein; the best flour is that which is extracted from the germ and this confirms the inferior protein efficiency found in the flours extracted from kernels and fragments because during industrial processing the germ tends to separate from the kernel very easily. Flour extracted from fragments rich in tegument has the lowest protein efficiency ratio; this value is confirmed by the presence of crude fibre found in higher quantity.

Conclusion

In conclusion, the data presented in this paper indicates a certain variability among the kernels coming from different places; however it is evident that the protein content found in flour extracted from cashewnuts has a very high food value; one of the highest among the proteins of vegetable origin. In particular the proteins of the germ appear to be superior to those contained in the whole kernel.

Cashew Seed and Oil Composition

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The cultivation of the cashew, *Anacardium occidentale* L. native to tropical American countries has been spreading throughout the two hemispheres, especially in the warm and temperate regions of Eurasia and America, (Tonzing, 1956 and Woodrof, 1967).

The botanical and growth characteristics of the cashew, its ecological needs, cultivation and growing techniques, phytosanitary defence, its products and their utilization, etc., have been recently described by Agnoloni and Giuliani (1977).

In the past few years production of cashew nuts has become very important especially for developing countries.

In the decade spanning the years from 1963 to 1972 the harvest has increased by approximately 40 per cent as compared to the previous decade; only in 1977 a 25 per cent decrease was experienced in the importation of cashew nuts by non producing countries and this is due only to an exceptional rise in the price of the nuts which occurred in that year. Otherwise, today's demand for shelled products appear to be on the increase.

Italy is not in the forefront of importing countries even though domestic consumption has increased in recent years.

The increase in consumption of cashew nut in Italy is mainly due to the efforts of Oltremare, S.P.A., Zola Predosa (Bologna), who, as well as importing the nuts, manufactures shelling plants and equipment for separating, the kernel from its wrapping.

Since 1969 Institute for Agricultural Industries has begun to interest itself in the chemical and physico-chemical characteristics of cashew seed and germ and also with testing the plant manufactured by Oltremare S.P.A.

During this same period other university institutes have carried out research on the nutritional aspects of the kernel (Piana et al. 1971 and 1972; Piana, Piva and Santi, 1974; Piva, Santi and Ekpenyong, 1971) and on the composition of the pericarp liquid (CNSL) (Kaufmann and Barve, 1967).

We have analyzed peeled cashew nuts, peeled by machine as such, unpeeled and refuse seeds; the germ, the tegument and the respective extraction meals (Pallota, Capella and Losi, 1969 and Strocchi et al. 1974).

The experimental procedures and the results achieved have been reported in detail in the above-mentioned papers.

In this report, we outline the chemical and physico-chemical characteristics of the main components the kernel and the germ, and summarise the results obtained.

Composition of the kernel (whether peeled by hand or by machine), the composition of refuse kernels and the composition of the germ, which is obtained by separating the kernel from the nut (by eliminating the tegument) during the shelling process used by Oltremare S.P.A. is given in table 1 along with composition of the main components of the ash.

TABLE 1. **Seed and Germ Composition**

	Peeled seeds	*Machine peeled seeds*	*Refuse seeds*	*Germ*
Moisture (%)	2.56	3.34	3.33	3.02
Protein (N x 6, 25) (%)	21.91	23.17	23.71	30.14
Fat (%)	49.12	49.50	45.79	29.53
Fibre (%)	0.68	0.95	0.98	2.57
Ash (%)	2.79	3.07	3.25	4.71
Sodium (ppm)	48	55	146	336
Potassium (ppm)	5421	5932	5211	10330
Calcium (ppm)	248	253	256	748
Magnesium (ppm)	2536	2540	2368	4240
Iron (ppm)	60	60	51	13
Copper (ppm)	22	25	21	3.9
Zinc (ppm)	38	40	34	15.3
Manganese (ppm)	18	18	14	7.7
Phosphorous (ppm)	8400	8600	9300	8760
Sulphur (ppm)	1600	1800	1800	2580
Chlorine (ppm)	tr.	tr.	tr.	510

The degree of moisture found in the different products is rather low, while the protein and raw fat contents, which vary significantly only between the kernel and the germ, is high. Of particular interest is the mineral element content.

The percentage of raw fat in the kernel is about the same as that found in the richer oil yielding seeds (peanuts, sesame, sunflower, etc.). The chemical and physico-chemical characteristics of lipids extracted by hexane are reported in table 2, together with the respective composition of fatty acids.

TABLE 2. **Chemical and Physical Characteristics of Oils**

	Peeled seed	*Machine peeled seed*	*Refuse seed*	*Germ*
Refractive index n_{20}	1.47	1.46	1.47	1.48
Acid value (% oleic acid)	1.30	2.20	6.20	2.70
Saponification value	193.10	194.90	183.70	189.70
Iodine value (Wijs)	86.70	86.40	87.20	91.20
Peroxide value	0.00	0.00	0.00	0.00
Oxidized fatty acids	absent	absent	absent	absent
Polyphenols (total) ppm	9.00	37.40	77.00	3.70
Unsaponifiable matter (%)	0.70	0.70	0.70	0.60
Fatty acids				
Palmitic (%)	10.30	11.50	10.80	11.60
Palmitoleic (%)	0.40	0.50	0.50	0.20
Stearic (%)	6.90	6.20	6.80	5.00
Oleic (%)	64.90	64.20	64.20	52.30
Linoleic (%)	16.70	16.80	16.90	30.90
Linolenic (%)	0.50	0.40	0.40	tr.
Eicosenoic (%)	0.30	0.40	0.40	tr.

It should be emphasized that the total polyphenolic content of the oil–located in particular in the tegument and correlated with stability of peroxidation of an oil–increase from the hand peeled kernel to the refuse seeds, while it is very low in the germ. Quantities found out on the refuse products are of the same magnitude as those found in olive oil (Cetrullo, 1977), and about ten times less than that found in grape-seed oil (Capella, Lerker and Tiscornia, 1974).

Apart from quantitative differences found between kernel oil and germ oil, the saturated and unsaturated acids content appears to be particularly interesting from a biological-nutritional point of view.

In particular, the unsaturated acid C_{18} content indicates that this kind of oil is comparable to other edible oils such as peanut oil and more closely to some kind of olive oil produced in warm climates (Vitagliano and Ruggiero, 1969).

The analysis of the position isomers of the monounsaturated fraction at C_{18} – carried out by means of GLC–MS on trimethylsilyloxy derivates (Capella and Zorzut, 1968) – has shown both for kernel and germ oils that the isomer Δ^9 (oleic acid) is clearly predominant and that there are small quantities of the isomer Δ^{11} (vaccenic acid); which is the same as in the case of olive oil (Zorzut and Capella, 1969).

Particular attention has been given to the study of unsaponifiable fractions of these oils because at the time the study was undertaken, knowledge on this subject was very limited.

In this research we used the most modrern analytical techniques from TLC to GLC–MS. Among the different samples examined the total unsaponifiable fraction was 0.7% approximately, equal to that in the most of the known edible oils (Itoh, Tamura and Matsumoto, 1973).

The unsaponifiable fractions were analysed for saturated and unsaturated hydrocarbons, alcohols and methylsterols, sterols and tocopherols.

The presence of almost equal quantities of saturated and unsaturated constitutents was found in the hydrocarbon fraction: among the first a homologous series of linear hydrocarbons from C_{18} to C_{34}, with a typical distribution; while among the unsaturated ones the main constituent was found to be squalene (GLC–MS).

Among the triterpene alcohols, no qualitative difference was observed between the kernel oil and the germ oil. Cycloartenol and 24–methylencycloartenol and smaller quantities of β – amiryn and butyrospermol were found present, although in different quantities.

Furthermore, limited quantities of methylsterols are undoubtedly present. In the sterol fraction, quantitative differences have been observed between the kernel and the germ. β – sitosterol is predominant in the kernel oil as well as in the germ oil, however, in the first oil the quantity of compesterol is about half of that of stigmasterol while this ratio is decidedly the reverse in the germ oil. Both oils show the presence of cholesterol in quite a visible quantity; this is in accordance with what has been observed in oils of different types of oil yielding seeds (Lercker, Lerici and Capella, 1976 and Strocchi et al. 1977).

Among the tocopherols the presence of $\propto$ –, ($\beta+\gamma$) and δ forms in identical quantities have been found both in the kernel and the germ oils.

During the separation by TLC of different unsaponifiable components of the kernel and the germ in the area typical to tocopherols, a band, absent in the same fraction of different vegetable oils and which was not fluorescent under Wood's light, was visible. This band was later studied and its main component identified.

Figure 1 shows, as an example, the GLC trace of trimethylsilyl ethers of the tocopherol band components of cashew germ oil. The more representative GLC peaks are 1 and 4: the last one was found to be made up of ($\beta+\gamma$) – tocopherol, while the more predominant peak quantitatively, peak 1, did not match up with any of the available standards.

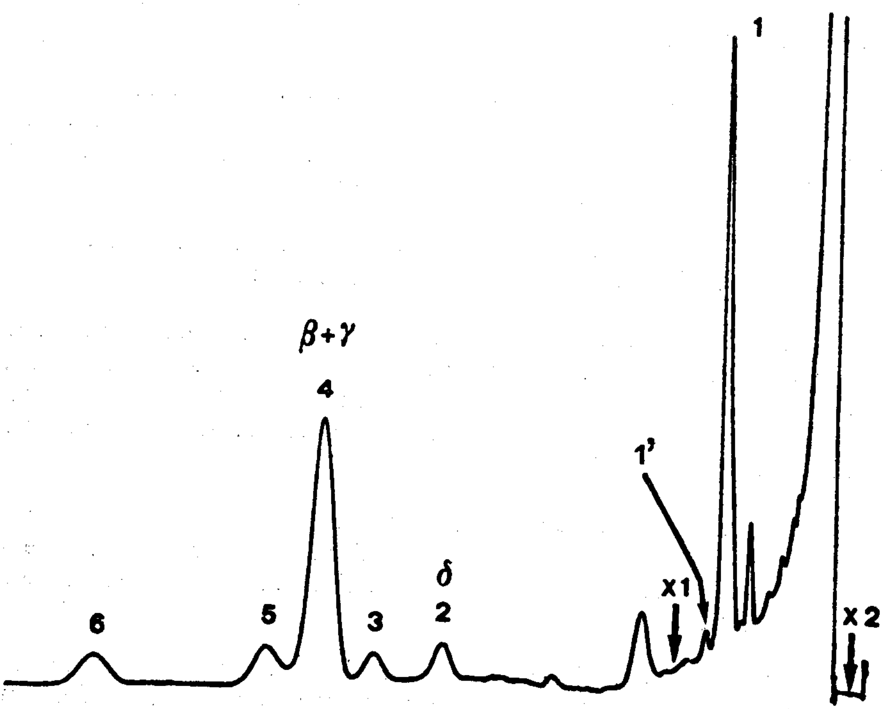


Fig. 1

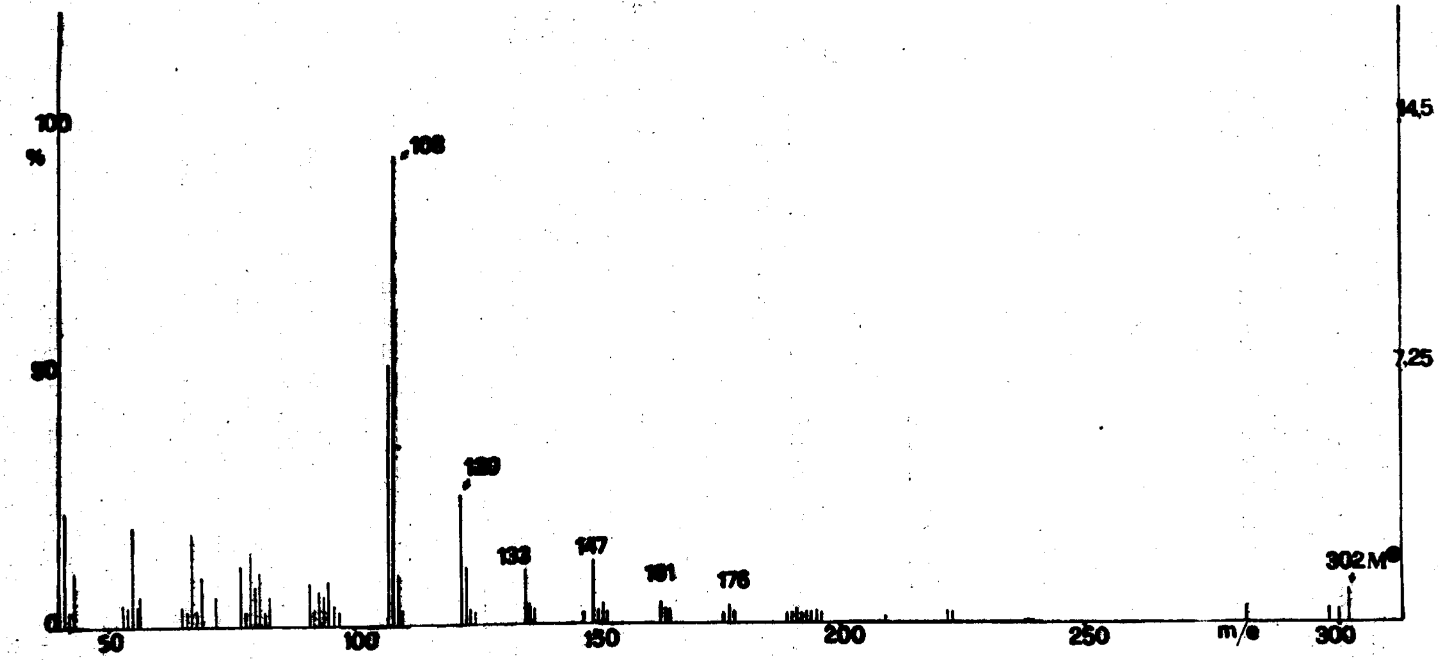
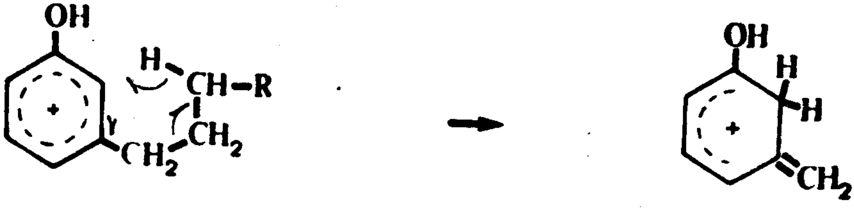


Fig. 2

Peak 1 mass spectrum (Fig. 2) leads one to think that a mixture of components having an equal number of carbon atoms, structurally similar, but with a different degree of unsaturation, is present. Further more the fragment itensity at m/e 108 has made possible the detection of the presence of a phenolic group, rationalized by the mechanism shown in Fig. 3.



m/e 302 (300–298) m/e 108

Fig. 3

The components corresponding to GLC peak 1 and 1' (Fig. 1) have been separated and collected by GLC preparative and analysed by GLC–MS.

The GLC trace is shown in Fig.4 and indicates that the components which can be separated for the experimental conditions adopted (polar column of SP 1000) (Lercker, Strocchi and Conte, 1975) are basically four. They correspond to the constituents of cardanol (Kaufmann and Barve, 1969) which originate from anacardol (Russel, 1969). Dealing with unsaturated compounds, after hydrogenation, analysis by GLC and GLC–MS have allowed us to confirm the presence of only one component with M.Wt. 304, corresponding to pentadecyl–phenol, in this fraction.

Infrared analysis of cardanol shows 870 cm^{-1} and 780 cm^{-1} absorption bands which indicate a connection in meta or 3 position in the hydrocarbon chain in the benzene ring (Szymansky, 1967).

The position of the double bond present in cardanol was determined by using the osmiate method (Capella and Zorzut, 1968) and by making a GLC–MS analysis of corresponding trimethylsilyloxy derivates, well separated by GLC. In this way we were able to locate the unsaturations in the lateral chain of substituted mono and di-unsaturated phenols respectively in position 8 and positions 8 and 11.

As for the tri-unsaturated component, given the complexity of the mass spectrum, we were able to locate the position of two double bonds with the method we followed, while the position of the third was confirmed by IR analysis on bands separated by TLC – Ag NO_3 of acetylderivatives.

Absorption at 905 cm^{-1} indicated the presence of a double bond in terminal position; therefore the 3-(8,11, 14-pentadecyl) phenol was found to be the triunsaturated component.

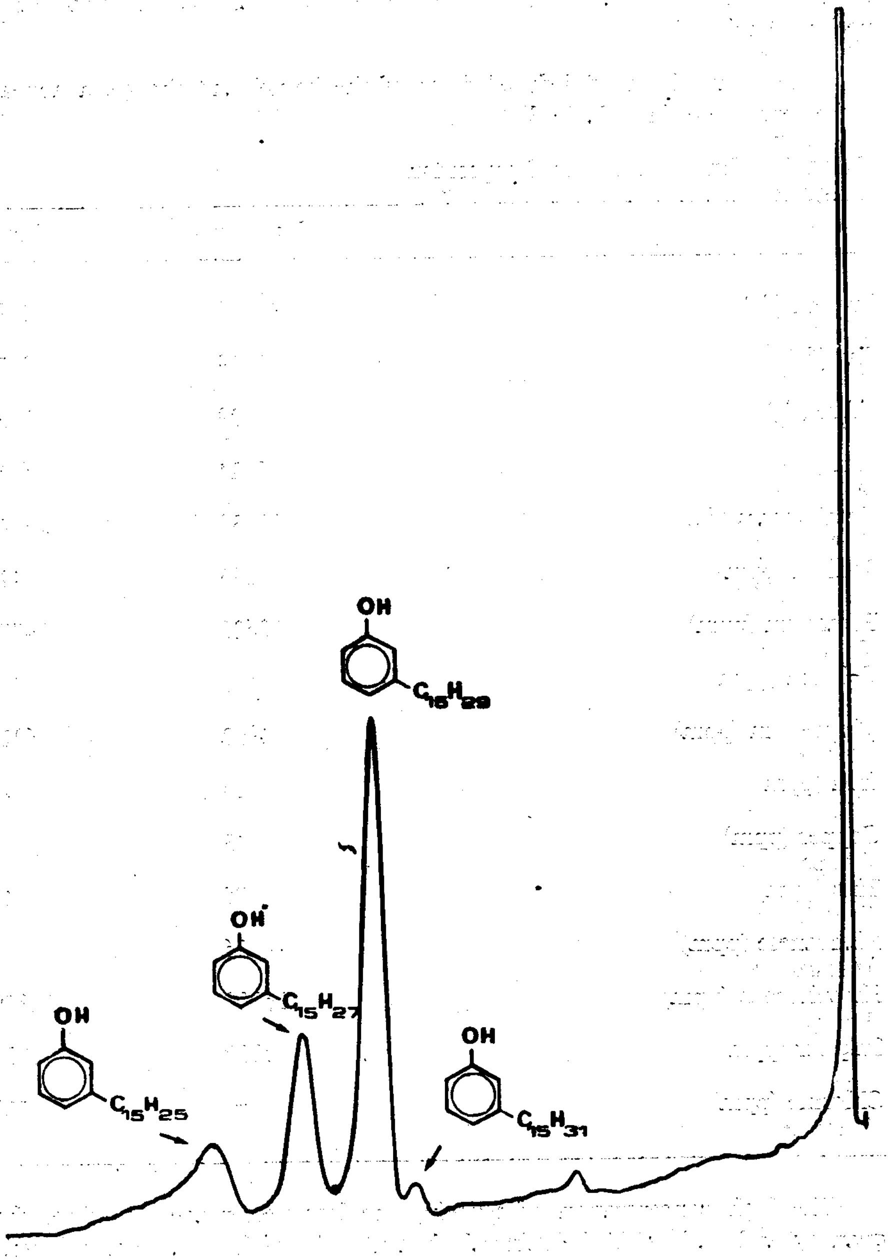


Fig. 4

These compounds are present in the germ oil to a great degree than in the kernel oil. However, we are dealing with rather small quantities in the order of 20 and 10 mg/100 ml of oil, respectively. Their presence could be attributed to natural origins or be the results of the system of mechanial peeling employed.

The composition of defatted flour of the kernel and the germ appears to be very interesting (Table 3).

TABLE 3. **Extraction Meals Composition**

	Cashew nut	*Germ*
Protein (%)	41.90	42.97
Fat (%)	1.29	0.77
Fibre (%)	1.39	1.97
Ash (%)	5.24	6.68
Total sugars (%)	11.30	19.44
Sodium (ppm)	195	423
Potassium (ppm)	10600	14770
Calcium (ppm)	475	1010
Magnesium (ppm)	4992	6020
Iron (ppm)	118	22
Copper (ppm)	43	8
Zinc (ppm)	75	47
Manganese (ppm)	36	8
Phosphorous (ppm)	16100	12870
Sulphur (ppm)	3000	1790
Chlorine (ppm)	tr.	520

The high concentration of protein, the low percentage of fibre, the quantity and variety of the mineral elements, the high sugar content, confirm the food value of these flours because the composition they present is quite similar to those meals which are considered to be of great value (Ruthowski, 1968).

Concerning the sugars, the GLC analysis on kernel meal has shown a predominance of saccharose together with smaller quantities of glucose and fructose while in the case of germ meal only saccharose seems to be present.

The aminoacid analysis of the total proteic fractions are presented in Table 4.

TABLE 4. **Amino Acid Composition of Extraction Meals**

	Cashew nut	*Germ*
Lysine	4.4	4.9
Histidine	1.8	1.8
Arginine	9.2	10.9
Aspartic acid	9.2	9.3
Threonine	3.4	4.5
Serine	4.8	4.9
Glutamic acid	22.8	18.1
Proline	3.6	3.8
Glycine	4.5	5.0
Alanine	4.1	4.9
Cystine	1.3	1.8
Valine	5.6	5.5
Methionine	1.4	1.8
Isoleucine	4.1	4.1
Leucine	7.2	7.6
Tyrosine	2.4	3.5
Phenylalanine	4.5	5.3
Tryptophan	1.1	1.0

There are 18 aminoacids present including all the essential ones for the monogastrics and man. Their content seems to be sufficiently balanced to be considered very similar, if not superior, to soy, peanut and sunflower meals. In fact the "proteic count" (Rose et al. 1967) calculated for the kernel meal amounted to 84.9.

It is concluded that cashew nuts are an excellant food with high biological-nutritional value due to the qualitative-quantitative composition of the proteic fraction; the fat content with low concentration of saturated and polyunsaturated; the sugar and mineral element contents as well as for the vitamins presence.

Even at the present time the kernels for the most part are merely used as "coktail snacks" and by the baking industry; but its use for direct human food consumption to satisfy both protein and energy needs should not be overlooked.

On the other hand utilizing the refuse kernel a very good edible oil and a valuable flour for zootechnical use can be obtained.

It is therefore worth while to increase and rationalize cashewnut cultivation and production, far beyond and economical advantages accruing to the agricultural sector of the producing countries, this tree produces a kernel that can be considered "the most versatile and remarkable of all nuts" for its outstanding nutritional and organoleptic characteristics.

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Compositional Studies on Natural Indian Cashew Nut Shell Liquid

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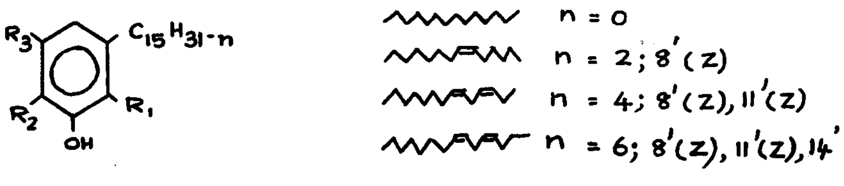
Abstract

The component phenols in Indian Cashew Nut Shell liquid of natural origin have been quantitatively determined by gas-liquid chromatography (GLC) after hydrogenation and silylation. The polymeric material present has been determined (by GLC) by the use of an internal standard. The unsaturated constituents (monoene, diene and triene) of each component phenol have been quantitatively determined by mass spectrometry on each component phenol after thin layer chromatographic separation. The mode of formation of the polymeric material and the influence of the age of the sample have been investigated.

Introduction

Previous compositional studies have been carried out by GLC on the hydrogenated and methylated component phenols (Tyman, 1976). The constituents of each methylated component phenol have been determined by GLC (Tyman, 1975) (with PEGA as the stationary phase) and complete resolution of the saturated, monoene, diene and the triene obtained. A quciker method has been to use the same preliminary TLC separation of the component phenols with mass spectrometry (Tyman, 1977a) to determine the unsaturated constituents. Corrective response factors are necessary in both the GLC and MS method and good agreement can been be obtained between the two procedures (Tyman, 1977b). By a GLC procedure incorporating the use of an internal standard the polymeric material in both natural and technical CNSL has been determined (Tyman, 1978).

The component phenols of natural CNSL from a number of different regions (Tyman and Lam, 1978) comprise anacardic acid (I; $R_1 = CO_2H$, $R_2 = R_3 = H$), cardol (I; $R_3 = OH$, $R_1 = R_2 = H$), 2 – methylcardol (I; $R_2 = CH_3$, $R_3 = OH$, $R_1 = H$) and cardanol (I; $R_1 = R_2 = R_3 = H$).



In the present work a compositional study of natural Indian cashew nut shell liquid has been made since it had not been possible at the time of analytical studies on other regional sources (Tyman and Lam, 1978) to obtain Indian material.

Since methyl ethers are not the simplest derivatives to prepare it seemed that the more easily derived trimethylsilyl ethers would be useful to evaluate in GLC analysis. As advantage of trimethylsilyl ethers is that they would permit analysis at a lower temperature and it was considered that they might enable the unsaturated phenols to be analysed with avoidance of the hydrogenation step. The advantage of a lower temperature in the GLC analysis can be seen with regard to the unsaturated phenolic acetates (Tyman, 1978), when at 230 °C, polymerisation to the extent of about 8 per cent occurred on the GLC column. As reference materials Mozambique and Brazilian cashew sources have been used alongside the Indian material with respect to percentage proportion of natural CNSL, component phenols (anacardic acid, cardol, 2 – methylcardol and cardanol) unsaturated constitutents (saturated, monoene, diene and triene) in each component phenol, and the polymeric material.

Extraction of Natural CNSL: Cashew nuts were shelled as described by Tyman (1973) and etherally extracted three times with diethyl ether. From the three sources the total recovered natural CNSL was found to be: Indian material (27.2%), Mozambique (22.5%) and Brazilian (27.2%).

Component Phenols: Thin layer chromotagraphy showed all three sources to be similar. They were hydrogenated with palladium/carbon and the saturated CNSL after incorporation of an internal standard (C24 n–hyrocarbon, tetracosane) silylated in the usual way with bistrimethylsilylacetamide and examined by GLC with 3 per cent Dexsil as the stationary phase. Table 1 shows the (normalised) composition of Indian, Mozambique and Brazilian natural CNSL with respect to the C15 phenols, anacardic acid, cardol, 2 – methylcardol and cardanol.

TABLE 1. **Composition of CNSL from Different Sources**

Source	*% Composition*			
	Anacardic Acid	*Cardol*	*2-Methylcardol*	*Cardanol*
Indian	87.8 ± 0.24	13.7 ± 0.15	2.5 ± 0.10	2.1 ± 0.10
Mozambique	79.9 ± 0.70	13.9 ± 0.50	2.8 ± 0.20	3.4 ± 0.10
Brazilian	79.8 ± 0.30	13.6 ± 0.20	2.9 ± 0.10	3.7 ± 0.10

It is clear that the species *Anacardium occidentale* produces the same general composition irrespective of the regional source.

With regard to non-volatile (polymeric material) present, table 2 gives the relative proportions of volatile and non-volatile components.

TABLE 2. **Volatile and Non-volatile Components of CNSL**

Source	*Composition*				
	% Non-volatile	*% Volatile*			
		Anacardic Acid	*Cardol*	*2–Methyl cardol*	*Cardanol*
Indian	26 9	58 8	10 0	1.8	1.5
Mozambique	28.2	57.4	10.0	2.0	2.4
Brazilian	25.9	59.1	10.1	2.2	2.7

Unsaturated Constituents: Following TLC separation of the component phenols and conversion of anacardic acid to methyl anacardate, the unsaturated constituents of each were determined by mass spectrometry. All results were corrected for isotopic contribution and relative response differences and the results are shown in table 3.

TABLE 3. **CNSL Analysis**

Component Phenol		*% Composition*			
		Saturated (15:0)	*Monoene* (15:1)	*Diene* (15:2)	*Triene* (15:3)
Methylanacardate	(Indian)	2.45	36.5	16.2	44.9
,,	(Mozambique)	2.45	36.3	16.7	44.6
Cardol	(Indian)	0.2	12.3	26.2	61.2
,,	(Mozambique)	0.3	10.5	21.7	67.6
2 – Methylcardol	(Indian)	1.4	27.6	24.4	46.5
,,	(Mozambique)	1.0	23.0	20.1	55.9
Cardanol	(Indian)	1.6	29.2	16.9	52.2
,,	(Mozambique)	1.6	29.2	16.5	52.7

Tables 2 and 3 indicate collectively that a total analysis of natural CNSL can be achieved.

Greater differences with Indian and Mozambique natural CNSL are shown between the percentage of unsaturated constituents than between the percentage of component phenols.

Comparison between analysis based on the use of silylated saturated and silylated unsaturated phenols: It would clearly be advantageous if the hydrogenation step in the analysis could be avoided and the natural CNSL be directly silylated and analysed. The purpose of hydrogenation was two-fold, first to prevent depolymerisation of polymeric material and secondly to avoid polymerisation of monomeric material. The use of excessively high temperature (250 °C and over) can lead to some polymerisation of unsaturated materials (Tyman and Wilczynski, 1978). Analytical results however obtained at lower temperatures are free from this and agreement between analyses of saturated and unsaturated silylated samples showed that polymerisation was not occuring.

Similar analysis to those with natural CNSL can be carried out with technical CNSL and lead to a compositional understanding of the material. Such results reveal the presence of rather more polymeric material, and the component phenols cardanol, cardol with small proportions of 2-methylcardol and residual anacardic acid. These results confirm that the conditions of decarboxylation invariably affect a good compromise between nearly complete decarboxylation and the onset of polymerisation.

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Discussion

A.S.L. Tirimanna: Is there any potential for the use of cashew phenolics as antioxidants in the rubber industry?

J.H.P. Tymen: Work has been done on antioxidants for the rubber industry based on cardanol and amines. The products were, I recall, quite as good as Phenylnaphtylamine and the compounds were patented and described in chemical abstracts.

M.S. Rajeevan: Is there any classification of CNSL into low, medium and high quality based on the chemical composition and use for which it is put to?

J.H.P. Tymen: For technical CNSL, quality is assessed on physical tests such as viscosity, iodine value and certain polymerisation tests. There is a correlation between these tests and chemical composition as that a high polymer content implies the presence of less monomers that is cardanol and cardol, particularly the later. Natural CNSL is not yet commercially processed. There is a case for having some natural CNSL, if new chemical uses are envisaged.

Recent Trends in CNSL Utilization

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Abstract

Cashew Nut Shell Liquid (CNSL) is a very important industrial raw material which has got multivarious uses. Considerable research work has been done on the utilization of CNSL in India and abroad. The main outlets for the utilization of CNSL and its derivatives are the brake lining industry, paint and varnish industry, laminated products, foundry core oil and rubber compounding. There is considerable scope for its utilization in the development of drugs, antioxidants, fungicides, etc. The main factors that are affecting the utilization of CNSL are its dark colour, variable quality and above all its high price.

Introduction

The cashew industry is the second biggest dollar earner of India. The cashew kernels and the cashew nut shell liquid are the two important products that are obtained from the cashew processing plant. Cashew nut shell liquid (CNSL) is obtained from the shells of the nuts and deoiled cashew cake. The cashew cake can be used as fuel or for production of activated carbons while the CNSL has tremendous potentialities as industrial raw material. The innumerable industrial applications of CNSL are based on the fact that the liquid lends itself to polymerisation and condensation reactions. Extensive research work has been done in India and abroad for the utilization of CNSL. In the present paper the current trends in the utilization of CNSL in India are discussed.

Research and Development of CNSL: A number of research organisations are working, or have worked on the utilization of CNSL with reasonable success, viz.,

(i) Regional Research Laboratory, Hyderabad (RRLH)
(ii) National Chemical Laboratory (NCL), Pune
(iii) Regional Research Laboratory (CSIR Complex), Trivandrum
(iv) Railway Designs and Standards Organisation, Lucknow
(v) Department of Chemical Technology, University of Bombay
(vi) Central Building Research Institute, Roorkee

Current outlets for the utilization of CNSL: Regional Research Laboratory, Hyderabad, carried out a survey on the production and consumption pattern of CNSL in India in 1977 (CEPC, 1977). The consumption of CNSL by various industries during 1971–78 are given in table 1. The main outlets for the utilization of CNSL and its derivatives were as follows:

Industry	*Estimated consumption of CNSL (tons)*
(i) Brake lining industry	1200 – 1400
(ii) Paint and Varnish	600 – 800
(iii) Laminated products	900 – 1000
(iv) Foundry Core oil	400 – 500

TABLE 1. **Consumption of CNSL by Various Industries (Tons).**

	1971	1972	1973	1974	1975	1976	1977	1978
Brake linings	850	900	950	1000	1100	1200	1350	1500
Paints and Varnishes	700	700	800	900	1100	1300	1600	1000
Chemical resistant cement	35	40	60	60	75	95	120	160
Oil tempered hardboards	40	40	40	50	50	70	80	100
Foundry core oil	550	600	600	700	850	1050	1300	1600
Epoxy resins	N	N	N	N	included in the estimate for cardanol.			
Laminates	150	150	150	included in the estimate for cardanol.				
Water proofing compound	—	—	10	16	20	20	30	32
Filter paper	—	—	—	—	150	150	150	150
CNSL based resins	N	N	10	20	50	50	50	50
Cardanol	380	630	720	850	1100	1340	1900	2280
Total	2705	3060	3340	3596	4495	5275	6580	7762

N = Negligible

Source: "Cashewnut Shell Liquid — Prospects for Expansion of Internal Consumption and Exports" by the Indian Institute of Foreign Trade, p. 45.

Brake lining industry: The major uses of CNSL in India is the brake lining industry which uses mostly CNSL resin and CNSL based friction dust. M/s Hindustan Ferrodo, Rane Brake Linings, Hindustan Brake Linings and Bramessuri are the major users of CNSL to the tune of 14,000 tons/annum.

Paints and varnishes: In view of its dark colour, CNSL is used only in the manufacture of dark-coloured paints and black enamels. The important products in which CNSL or its derivatives are used are anticorrosive primers, black enamels and marine paints. Its usage varies with the individual unit depending upon the products mix, its level of technology and the extent of R and D facilities. According to some estimates the present consumption of CNSL is about 300 to 400 tons per annum. The important surface casting materials in which CNSL finds use are as follows:

(i) *Bituminous emulsions*

Bituminous emulsions based on CNSL have been developed in metallurgical and chemical research wing of Research Designs and Standards Organization, Lucknow (Ramanujam 1960 and 1961).

(ii) *Water and weather proofing coatings*

Resin compositions based on CNSL were developed at Central Building Research Institute, Roorkee. This composition is fully resistant to water and weather. It may find wide applications in the building industry.

(iii) *Anticorrosive coatings for ships' bottom*

Regional Research Laboratory, Hyderabad, has developed an anticorrosive primer from cashew nut shell liquid suitable for application on ships' bottom (Agarwal et al. 1967). The Central Institute of Fisheries Technology, Cochin, has developed a specialized protective coating for wooden surfaces of fishing boats.

(iv) *Cardanol and compositions based on cardanol*

Extensive work has been carried out at Regional Research Laboratory, Hyderabad on the production of cardanol and various types of varnishes and lacquers from cardanol. The cardanol is obtained in 60 – 70 per cent yield by distillation of CNSL under low pressures and about 30 – 35 per cent of a polymerised residue is also obtained in the process.

(v) *Composition based on cardanol and CNSL*

Lacquers of different types suitable as coatings, insulating varnishes, furniture coatings and as media for quick drying enamels have been formulated. Vinyl modified resins based on cardanol have given films of excellent properties. Pale coloured adhesives have been obtained by reaction of cardanol formaldehyde resin with epichlorohydrin. Cardanol based epoxy resins have also been prepared.

As the film of the CNSL or cardanol based lacquers have very high electric insulation, they are useful as insulating and impregnating varnishes. Coating compositions based on CNSL residue have also been developed. They are suitable for use as enamels for sewing machines and bicycles. There are at present three units manufacturing cardanol in India. Two are located in Hyderabad and one in Bombay. Their total installed capacity is about 1300 - 1500 tons while their annual production is about 600 - 700 tons using 1200 - 1500 tons of CNSL. Besides cardanol, they also manufacture CNSL resins, polymerised CNSL and resins based on cardanol. The production of cardanol and cardanol based resins has been seriously affected during the last two years due to high price and shortage in the supply of CNSL.

(vi) *Coatings based on CNSL distillation residue*

As the media based on CNSL distillation residue give very hard films on baking, they can be used in the formulation of slate paints. RRLH developed know-how for the preparation of black slate enamels based on CNSL or CNSL distillation residue pigmenting with silica and emery powder. A firm from Markapur, Andhra Pradesh, is using the above know-how and manufacturing the slates using thin sheets of mild steel. Also a coating based on CNSL distillation residue was successfully used for coating the interior of ferroconcrete domes used for the collection of gober gas. CNSL distillation is also used as coating of light roofing corrugated sheets for increasing durability.

(vii) *Insulating varnishes from CNSL and cardanol*

The clear lacquer prepared from CNSL or cardanol was found to be very good insulating varnish. The average break-down voltage per mil of the film thickness of CNSL varnish was more than 2 - 3 kv. M/s Beck & Co., Pune, is reported to be using sizable amount of CNSL in the manufacture of insulating varnishes.

(viii) *Production of hydrogenated cardanol* (3-pentadecyl phenol)

Hydrogenated cardanol or 3-pentadecyl phenol is obtained by the hydrogenation of the olefinic side chain of cardanol. A process has been developed at RRLH for the preparation of hydrogenated cardanol which can be used in the preparation of resin, surfactants, azo dyes, etc. (Madhusudhan et al. 1973 and Sundara Ramaiah et al. 1973).

(ix) The lamination industry in India consumes annually about 900 to 1000 tons of CNSL for the manufacture of laminating resins in the form of cardanol. Bakelite Hylam, Hyderabad, Formica, Pimpri and Caprihans India Ltd., are the major users of CNSL or cardanol for this purpose. Cardanol resins are mostly used in the preparation of industrial laminates to provide better flexibility. In the lamination industry, the use of cardanol depends on the price of CNSL.

Foundry core oil: CNSL is also being used as replacement of linseed oil in the manufacture of foundry core oil which is used as a binder in the foundries. The annual consumption of CNSL in the manufacture of core oil may be around 500 to 600 tons. M/s Greaves Foseco, Pune, and M/s Gargi Industries, Chembur, are among the major users of CNSL in the manufacture of foundry core oil. In this industry also the use of CNSL depends on its price relative to that of linseed oil.

Rubber compounding industries: Some firms are reported to be using CNSL in processing of rubber. No reliable figures are available regarding the consumption of CNSL and its derivatives by this industry. Rubber Research Institute, Bombay, has developed a technology for the preparation of rubber compounding compositions from CNSL and CNSL distillation residue.

Surfactants: National Chemical Laboratory, Pune, has developed a process for the preparation of surfactants based on cardanol and hydrogenated cardanol (Gulati and Subbarao, 1966 and Krishnaswamy, Govindan and Pandya, 1957).

Polyurethane adhesives, foams and coatings: National Chemical Laboratory, Pune, has developed a process for the production of adhesives and foams based on CNSL. Regional Research Laboratory, Hyderabad, has patented a process for the preparation of cardanol based polyurethane adhesives.

Factors affecting the utilization of CNSL in India: The main factors that are affecting the utilization of CNSL in various industries are:

(i) Its dark colour limits its use in the surface coatings and other industries. Conversion of CNSL into cardanol and hydrogenated cardanol helps to some extent in overcoming this disadvantage.

(ii) The quality of CNSL is not uniform which results in batch to batch variation in the end products.

(iii) The use of CNSL in the paint industry involves its condensation with aldehydes and hence attracts excise duty to the extent of 18 per cent. Unless there is sufficient difference in the price of CSNL and linseed oil to offset the above additional cost, the paint manufacturers do not find any advantage in the use of CNSL.

(iv) The utilization of CNSL or cardanol mostly depends on its price and easy availability. There is good scope for the increasing utilization of CNSL in surface coating, lamination and other industries if the liquid is made available at reasonable prices.

Scope of the utilization of CNSL in new areas: As stated above the high price of CNSL and its derivatives limits its utilization in surface coatings, brake lining, and attempts are being made to explore the areas where this important material can be advantageously used. The researches carried out in various laboratories have definitely shown that CNSL derivatives can advantageously used in the preparation of antioxidants, bactericides, fungicides, disinfectants, insecticides, pesticides, herbicides and drugs. Recently a number of derivatives of 3-pentadecyl phenol have been synthesised (Ramalingam, 1976). Processes for the preparation of α - (3 - pentadecyl acryloxy) propionic acids and their derivatives and α - (3- pentadecyl acryloxy) isobutyric acids and their esters have been developed and patented. They were found to have good pesticidal and pharmacological properties.

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The Structure of the Gum of *Anacardium occidentale*

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Abstract

The gum from the cashewnut tree occurs in the form of pale yellow to reddish stalactic masses. In cold water it swells up into a jelly like mass but dissolves rapidly when heated. Due to its insecticidal and good adhesive properties, the gum finds extensive application in book binding. An electrophoretically pure acidic polysaccharide, $[\alpha]D^{22}$ + 18.03°, M.W. 6.412 x 10^4, has been isolated from this gum. Its structure has been elucidated from immunochemical reactions, hydrolysis under different conditions, methylation, and periodate oxidation studies. Complete acid hydrolysis shows that cashew gum is built up of D-galactose, L-arabinose, D – galacturonic acid and L–rhamnose (in traces). Cross reactions with different anti-sera confirm the presence of non-reducing galactose units reinforced in some cases with L–rhamnose residues in the gum. Autohydrolysis of the gum generates a degraded gum, M.W. 23250, which upon graded hydrolysis furnishes an aldobiouronic acid the structure of which has been established as 6 – 0 – (ß – D – galactopyranosyl uronic acid) – D – galactose. Finally, the structures of degraded and natural cashew gums have been settled from the result of methylation, periodate oxidation followed by Smith degradation experiments. Degraded cashew gum is a branched chain polysaccharide and its repeating unit consists of a 1 → 3 linked galactan main chain to which are attached galactose residues by 6 → 1 linkages as side chains. Every alternate galactose residue constituting the branch carries aldobiouronic acid moieties also joined by 6 → 1 linkage. The natural cashew gum differs from the degraded gum with respect to the size of the main galactan chain and in the number of auxilliary chains. In addition, the natural gum carries a side chain L–Araf (1 → 3) L–Arap (1. . . .attached to a galactose moiety of one of the auxilliary chains). The D.P. values of the degraded and natural cashew gum, as calculated from the molecular weights, were found to be 17 and 13, respectively.

Introduction

The bark of the cashewnut (*Anacardium occidentale,* L.) tree exudes a pale yellow to reddish gum in staletiform masses. It is partly soluble in water, the major portion swelling up into a jelly like mass. Due to its adhesive

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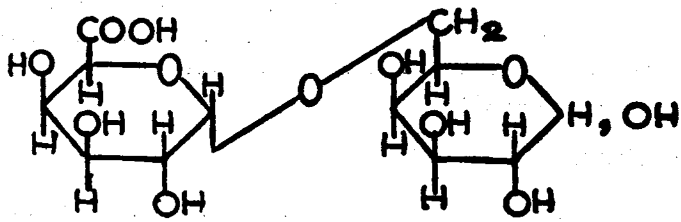
properties and insecticidal nature, the gum finds extensive application in book binding. Since the nature of this gum has remained uninvestigated so far, a systematic chemical examination has been undertaken to elucidate its composition and structure.

Results and Discussion

The crude gum was purified by repeated fractional precipitation from an aqueous solution with ethanol to yield a white power $[\alpha]D^{20}$ + 18.03°, pentoses, 5.35, anhydrouronic acid, 4.34 and ash 0.15%. Free boundary electrophoresis of the pure sample produced a single symmetrical peak, showing the presence of a single negatively charged component with mobility values ($\mu = 7.9 \times 10^{-5}$ cm^{-2} Sec^{-1} $Volt^{-1}$). The homogenesity of the compound was also confirmed from its sedimentation pattern and I.R. spectrum. Pure gum does not reduce Felhing's solution and possesses an Eq. Wt. 5130 and M.W. 6.412×10^4.

The cross reactivity of an homogeneous sample of the gum with various types of anti-Pneumococcus, anti-Typhoid and other anti-sera indicated certain salient features of its structure. The strong reaction with anti-Pn IV shows the presence of multiple units of 1–linked D–galactose units in *A. occidentale* gum while the reaction with other anti-sera might be due to the presence of D–galactose reinforced in some cases with L–rhamnose residues. The reaction with anti-Pn VII suggests that the terminal D–galactose residues are probably β–linked (How, Brimacombe and Stacey 1964). Complete acid hydrolysis shows that the gum is built up of D–galactose, L–arabinose, D–galacturonic acid along with traces of rhamonse (Bose and Biswas, 1970). A quantitative acid hydrolysis indicates that the two major sugars, D–galactose and L–arabinose, are present in the gum in the proportion of 17:1.

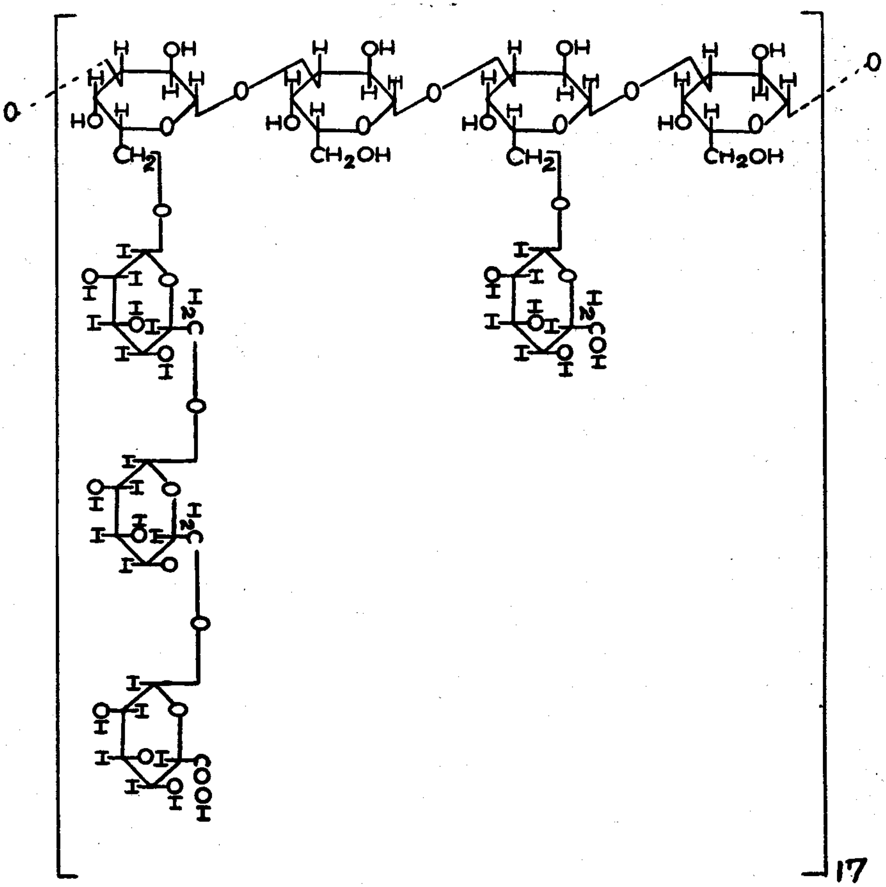
Autohydrolysis of the gum generates a degraded gum which on graded hydrolysis furnishes an aldobiouronic acid (I). Acid hydrolysis of (I) shows that it is composed of D–galactose and D–galacturonic acid only. The mode of linkage between these two moieties was finally settled from the hydrolysis of methyl hepta-o-methyl aldobiouronate (II), $[\alpha]$ D^{28} + 20.6°, when 2:3:4-tri–o–methyl–D–galactose and 2:3:4–tri–o–methyl–D–galacturonic were obtained in equimolecular proportions and identified. Further (II), upon reduction with sodium borohydride followed by acid hydrolysis, gave irse to a single methylated sugar, 2:3:4-tri-o-methyl-D–galactose. Periodate oxidation of methyl ester methyl glycoside derivative of (I) liberates nearly two moles of formic acid with concommitant consumption of approximate four moles of periodate. From all these observatiens, the adlobiouronic acid has been assigned a structure 6–0–(β–D–galactopyranosyl uronic acid) –D–galactopyranose (I).



(I)

Degraded *A. occidentale* gum, Eq. Wt. 1227, M.W. 2.325 x 10^4 on complete acid hydrolysis breaks down to galactose (7 moles) and galacturonic acid (1 mole). Its I.R. spectrum shows two weak absorption bands at 890 (hump) and 780 cm^{-1} suggestive of a β 6 → 1 linkage (Barker, et al. 1954). Completely methylated degraded gum on acid hydrolysis gave rise to 2,3,4,6–tetra-- (1 mole), 2,4,6–tri- (2 moles), 2,3,4–tri– (2 moles) and 2,4–di-o-methyl-D– galactoses (2 moles) and 2,3,4–tri-o-methyl –D–galacturonic acid (1 mole). All the methylated sugars were identified from their migration rates, specific rotations and the m.p.'s of their characteristic crystalline derivatives. The methylation analysis shows the presence of terminal non-reducing end groups D–galactopyranose and D–galactopyranosyl uronic acid, 3–o– and 6–o– and 1,3 di-o-substituted D–galactopyranose residues in the molecular complex of the degraded gum. Accordingly a tentative structure (III) is advanced for the repeating unit of the degraded *A. occidentale* gum which can accommodate all the types of linkages mentioned. The results of periodate oxidation and Smith degradation studies are also in agreement with the proposed structure.

Upon oxidation with sodium metaperiodate, the degraded gum consumes 7.92 moles of oxident with simultaneous liberation of 3.92 moles of formic acid per average repeating unit. Hydrolysis of the periodate oxidised degraded gum gives rise to galactose residue (4 moles) which had survived oxidation. Finally the periodate oxidised compound was subjected to Smith's degradation by reduction with sodium borohydride followed by hydrolysis with acid. The hydrolysis showed the presence of galactose, glycerol and glycolaldehyde fragments. A quantitative estimation revealed the molar proportion of galactose and glycerol as 1:1 approximately. All these results are very much comparable with the theoretical values expected from the proposed structure (III). In the structure of degraded *A. occidentale* gum, the glycosidic bonds have been assigned β – configuration since the I. R. spectra of both degraded gum and its permethylated product show absorption bands in the region of 891 + 7 cm^{-1} which may be ascribed to a linkage of B –D– type. The cross reaction of the gum with anti–Pn VII serum and the isolation of a β–linked aldobiouron also corroborate the above assignment.



(III)

The loss of L–arabinose residues as a result of autohydrolysis gives rise to degraded gum of *A. occidentale.* Hence a knowledge of the mode of attachment of these L–arabinose residues to the degraded gum will provide an insight into the structural framework. To obtain this information, *A. occidentale* gum was completely methylated followed by hydrolysis with acid. This resulted in the isolation of six methylated sugars which were identified as 2,3,5–tri–, 2,4-di-o-methyl–L–arabinose, 2,3,4,6–tetra–, 2,3,4–tri–, 2,4,6–tri–, and 2,4–di–o–methyl–D–galactoses and 2,3,4-tri-o-methyl–D–galacturonic acid. The weights of the individual components indicate that tri-o-methylarabinose, tetra-o-methylgalactose, tri-o-methylgalactose, di-o-methylarabinose, di-o-methylgalactose and tri-o-methyl galacturonic acid are in an approximate ratio of 1: 7: 12: 1:9: 1. Hence it can be seen that the acid hydrolysate of methylated *A. occidentale* gum carries higher proportion of di-, tri-, and tetra-o-methyl-galactoses as compared to that of methylated degraded gum. The occurrence of two methylated arabinoses viz., 2,4-di-o-methyl and 2,3,4-tri-o-methyl-L-arabinose is indicative of the existence of a side chain of the type L-Araf (1 → 3) L - Arap (1 — in *A. occidentale* gum. The methylation results also point out that the number of non-reducing end groups in an average repeating unit of *A. occidentale* gum is nine as compared to two only in case of the degraded gum. This clearly shows that *A. occidentale* gum is highly branched in nature. The main structural feature appears to be same as that of the degraded *A. occidentale* gum but the former differs from the latter with respect to the size of the main galactal chain and also in the number of auxilliary chains. In addition, *A. occidentale* gum carries an additional side chain -L-Arap (1 →3) attached to a galactose moiety of one of the auxilliary chains. The presence of multiple branching and the occurrence of a large number of 1 → 3 and 1 → 6 linkages in the structural framework of *A. occidentale* gum receive further confirmation from the periodate oxidation data.

Experimental procedure: Unless otherwise stated, all evaporations were carried out under reduced pressure. Specific rotations are equilibrium values and m.ps. are uncorrected. Paper chromatographic analyses were carried out with the following solvent mixtures: (S_1) n-butanol-ethanol-water (5:1:4, upper layer), (S_2) n-butanol-acetic acid-water (4:1:5, upper layer) and (S_3) ethyl acetate-acetic acid-water (9:2:2). The following spray reagents were used for detecting the sugar spots: (R_1) alkaline silver nitrate, (R_2) p-anisidine hydrochloride, (R_3) ethanolic solution of aniline (1 %) and trichloroacetic acid (5 %) and (R_4) sodium metaperiodate and benzidine B. Rg denotes the migration rate of the sugar on paper chromatogram corresponding to that of 2,3,4,6- tetra-o-methyl-D-glucose. I.R. spectrum was taken with a Perkin-Elmer Infracord spectrophotometer, model 137 - B. Electrophoresis experiment was conducted with 1 per cent solution of polysaccharide in sodium tetraborate (0.05 M) using Spinco model H apparatus and sedimentation analysis was performed at 59,780 rpm with Spinco model-E ultracentrifuge. The anilide derivative of the methylated sugar was prepared by refluxing an ethanolic solution of the methylated sugar with freshly distilled aniline for 1 hour on a steam bath.

Purification of A. occidentale gum: An acidified aqueous solution of crude gum (25 g in 450 ml) was poured slowly with constant stirring into a large excess of ethanol (4 litres) when a white flocculant precipitate was obtained. The process was repeated thrice to obtain the pure gum as a white powder, yield 14.25 g, $[\alpha]_D^{22}$ + 18.03° (c, 1.08 in water); pentoses 5.35, anhydrouronic acid, 4.34 and ash 0.15 %. Nitrogen, sulphur, halogen and methozyl were absent. Its I. R. spectrum in Nujol showed absorption bands at 3333, 2857, 1724, 1613, 1351, 1063, 1043, 890 (hump) and 775 cm^{-1}. The ionic mobility (μ) of the borate complex of the pure gum acid was found to be 7.9 x 10^{-5} cm^2 Sec^{-1} $volt^{-1}$. It is non-reducing in nature and has an Eq. Wt. (by titration), 5130 and M. W. (by sedimentation velocity method), 6.412 x 10^4.

Cross reactivity of A. occidentale gum with different types of sera: Pure gum acid (50 and 150μg respectively in two separate experiments) was added to different types of sera (1 ml). The mixture was left undisturbed at 0 – 5° for seven days or more. The extent of reaction in terms of precipitate formed was recorded in the scale of (–) to (++++) and the results were as follows: Anti-pneumococcus I (– ±), II (+±, ++±), V(++), VI(+±, +±), VII (++±), IX (+±), XII (++, ++), XIV (++±, +++), XIX (+, +±), XX (–, ++), XXII (+++, +++±), XXIII (++, ++), XXV (–, +±), Anti-salm typh. (+++, ++±), Anti-para typh. A (+++, ++±), Anti-para typh. B (++, ++), Anti-mycoplasma mycoides (++±, +++).

Complete acid hydrolysis of the gum: Gum (10 g) was hydrolysed with sulphuric acid (2N, 300 ml) for 40 hrs. and the hydrolysate was worked up into two fractions (A), mixture of neutral sugars and (B), barium salt of uronic acid. (A) was resolved by cellulose column chromatography, using n-butanol half saturated with water as eluant into three homogeneous sugar moieties–rhamnose (in extremely poor yield) m.p. and m.m.p. with an authentic sample 93 – 94°; L–arabinose, $[\alpha]$ D^{22} + 104° (c, 0.04 in water), m.p. and m.m.p. 155 – 6°, p–nitro–N–phenyl–L–arabino–sylamine, m.p. and m.m.p. 205° and D–galactose, $[\alpha]$ D^{22} + 82.4 (c, 1.10 in water), m.p. and m.m.p. 167°, p–nitro-N-phenyl-D-galactosylamine, m.p. and m.m.p. 205°. When treated with basic lead acetate (Ehrlich, 1945) and cysteine hydrochloride (Dishe, 1948) in presence of concentrated sulphuric acid, fraction (B) developed pink and greenish blue colour respectively characteristic of D–galacturonic acid. Further (B) on oxidation with concentrated nitric acid furnished mucic acid, m.p. and m.m.p. 212°. Methyl ester methyl glycoside derivative of (B), on reduction with sodium borohydride and subsequent hydrolysis with sulphuric acid (N) for 10 hrs, produced galactose only identified by paper chromatography (Solvent S_1, Spray reagent, R_1). A quantitative acid hydrolysis of the gum followed by estimation of the liberated sugars with sodium metaperiodate (Hirst and Jones, 1949) showed that D–galactose and L–arabinose were present in a molar ratio of 17:1.

Preparation of degraded A. occidentale gum and its graded hydrolysis: An aqueous solution of *A. occidentale* gum (20 g in 500 ml) was autohydrolysed by heating on a steam-bath for 90 hrs. The autohydrolysate after neutralization (barium hydroxide) was concentrated to a syrup and extracted with boiling dry methanol (250 ml). The methanol insoluble residue was further purified by refluxing with excess of dry methanol when degraded *A. occidentale* gum was obtained as a light yellow powder, yield 14 g, Eq. Wt. 1327, M.W. 2.325×10^4. Its I.R. spectrum showed absorption bands at 3333, 1602, 1370, 1143, 1075, 890 (hump) and 780 cm^{-1}.

Degraded gum (10 g) was subjected to graded hydrolysis with sulphuric acid (0.1 N, 200 ml) for 40 hrs. on a steam-bath. The hydrolysate after neutralization with barium carbonate was concentrated to a syrup. This on treatment with boiling dry methanol furnished an almost white powder (Found: Ba, 15.8) Aldobiouronic acid barium salt, $(C_{12} H_{19}, O_{12})_2$ Ba (requires Ba, 16.2%). Paper chromatography of the sample (Solvent S_2 and S_3, spray reagent R_2) furnished a single pink spot. Barium salt (0.1 g) upon complete hydrolysis with sulphuric acid (N, 15 ml) for 30 hrs. on a steam-bath gave rise to D–galactose and D–galacturonic acid which were identified as described earlier. Another portion of the barium salt (0.5 g) was converted into its methylester methyl glycoside derivative by treating with methanolic hydrogen chloride (4%, 25 ml) for 4 hr. This was then reduced with sodium borohydride (0.9 g) and hydrolysed with sulphuric acid (N, 20 ml) to furnish D–galactose only.

Methylation of aldobiouronic acid and hydrolysis of methyl hepta-o-methyl aldobiouronate: Aldobiouronic acid (barium salt 1 g) was completely methylated by first treating with dimethyl sulphate and alkali according to the procedure of Aspinall and Fairweather, (1965) followed repeated treatment with Purdee's reagent. Finally a brown viscous liquid was obtained, yield 0.79 g, $[\alpha]\ D^{28} + 20.6°$ (c, 1.07 in chloroform), (Found: $-OCH_3$, 51.3). Methyl hepta-o-methyl aldobiouronate, $C_{20} H_{36} O_{12}$, (requires–OCH_3, 52.9%). The I. R. spectrum of the compound showed, absence of absorption band for hydroxyl group.

Methyl hepta-o-methyl aldobiouranate (1.19 g) was hydrolysed by heating with methanolic hydrogen chloride (4%, 80 ml) for 10 hrs. followed by sulphuric acid (N, 80 ml) for 10 hrs. The hydrolysate on being worked up gave a viscous syrup. This was made alkaline (pH 9.0) and extracted with chloroform to yield methylated neutral sugar. The aqueous alkaline solution after acidification (pH 2.0) was extracted with chloroform to furnish methylated uronic acid. The neutral methylated sugar $D^{28} + 140°$ (c, 0.19 in water), gave a reddish yellow spot (Rg 0.65) on paper chromatography (Solvent S_1, spray reagent R_2). It was identified as 2,3,4–trio-o-methyl-D-galactose from its methoxyl value (OCH_3, 40.99%) and also by conversion to 2,3,4–tri-o-methyl-N-phenyl-D-galactosylamine, m.p. and m.m.p. 165 – 7°. The acidic methylated sugar produced an intense red spot (Rg, 0.63) on paper chromatography (Solvent S_2, spray reagent R_3) (Found:– OCH_3, 35.92. Tri-o-methyl galacturonic acid, $C_9H_{16}O_7$, H_2O requires –OCH_3, 36.7%). Its identity was confirmed as 2,3,4–tri-o-methyl-D-galacturonic acid by its conversion to 2,3,4–tri-o-methyl-D-galactosaccharic acid dimethyl ester (Parikh, and Jones, 1966) m.p. 101° and 2,3,4-tri-o-methyl-D-galactose (anilide, m.p. 167°).

Reduction of methyl hepta-o-methyl aldobiourate and its hydrolysis: An aqueous solution of methyl hepto-o-methyl aldobiouronate (0.25 g in 30 ml) was reduced with sodium borohydride (0.5 g). After working up the resulting product was hydrolysed with sulphuric acid (2N, 15 ml) when a syrup was obtained, yield 0.17 g. This was identified as 2,3,4-tri-o-methyl-D-galactose in the same manner as described above.

Periodate oxidation of methyl ester methyl glycoside derivative of aldobiouronic acid: An aqueous solution of the compound (0.335 g in 50 ml) was treated with sodium metaperiodate solution (0.649 g in 25 ml) and kept as such in dark for 7 days at 20 °C. The volume of the solution was made up to 250 ml and aliquots (5 ml each) were withdrawn after regular intervals of time for the estimation of periodate consumed and formic acid liberated as a result of oxidation. Periodate consumed and formic acid liberated at the final stage was found to be 2 and 4 moles respectively per mole of the compound.

Methylation of the degraded gum and hydrolysis of the methylated derivative: Degraded *A. occidentale* gum (30 g) was first methylated by treatment with sodium hydroxide (300 ml, 30%) and dimethyl sulphate (200 ml) according to the procedure of Haworth. The partially methylated compound was further methylated twice by Purdee's method by treating with methyl iodide (80 ml) and freshly prepared silver oxide (16 g). Finally a light yellow syrupy liquid was obtained (yield 18.20 g) (Found–OH_e, 41.98%). The I.R. spectrum of the compound in Nujol showed absence of absorption band for –OH but contained other absorption bands at 1739, 890 and 769 cm^{-1}.

Fully methylated degraded gum (7.8 g) was hydrolysed with cold sulphuric acid (72%, 50 ml) for 1 hr. The strength of the acid was then reduced to 12 per cent and the resulting mixture was heated on a steam bath for 4 hrs. The solution was cooled, neutralised (barium carbonate) and concentrated to a thick syrup. This was made alkaline (pH 8.0) and extracted exhaustively with ethyl acetate to obtain the mixture of neutral methylated sugars (5.04 g). The alkaline solution after acidification and similar extraction with ethyl acetate furnished the acidic methylated sugar (0.68 g) which was identified as 2,3,4-tri-o-methyl-D-galacturonic acid as described above. Resolution of the mixture of neutral methylated sugars into its individual components was conducted by preparative partition chromatography on Whatman No. 3 filter paper sheets (Solvent S_1). The strips corresponding to the individual methylated sugars were eluted with water to obtain the following fractions:

1. 2,3,4,6–tetra-o-methyl-D-galactose (Rg 0.89), $[\alpha]_D^{30} + 114°$ – It furnished a crystalline anilide, m.p. and m.m.p. 190°.

2. 2,4,6–tri-o-methyl-D-galactose (Rg 0.67), [α] D^{30} + 92° – It furnished a crystalline anilide derivative, m.p. and m.m.p., 177 – 8°.

3. 2,3,4–tri-o-methyl-D-galactose (Rg 0.65), [α] D^{30} + 142° – It gave a crystalline anilide derivative, m.p. and m.m.p. 165 – 6°.

4. 2,4–di-o-methyl-D-galactose (Rg 0.40), [α] D^{30} + 86° – It crystallized from ethyl acetate in the form of needles, m.p. 103 – 04°. It gave a crystalline 2,4-di-o-methyl-N-phenyl-D-*galactosylamine*, m.p. and m.m.p. 216 – 7°.

A quantitative estimation of the neutral methylated sugars by the hypoiodite oxidation method (Chanda et al. 1950) showed that 2,3,4,6–tetra–, 2,4,6-tri–, 2,3,4-tri–, and 2,4-di-o-methyl-D-galactoses were present in a molar ratio of 1:2:2:2.

Periodate oxidation of the degraded gum: An aqueous solution of the degraded gum (0.2054 g) was mixed with sodium metaperiodate solution (0.15 M, 25 ml) and the volume was made up to 250 ml with water. It was kept in the dark at room temperature for 7 days. Aliquots (5 ml each) were withdrawn at regular intervals to estimate the consumption of periodate and the liberation of formic acid. The amount of periodate consumed was 7.92 moles with simultaneous liberation of 3.92 moles of formic acid per average repeating unit. An aqueous solution of periodate oxidised degraded gum was treated with ethylene glycol to destroy excess of periodate. After removal of inorganic ions by dialysis, the solution was concentrated to a syrup and hydrolysed with sulphuric acid (N, 10 ml) for 4 hrs. to liberate galactose (4 moles) per equivalent of the degraded gum.

Smith degradation of periodate oxidised degraded gum: An aqueous solution of periodate oxidised degraded gum (0.15 g) after being freed from excess of periodate and other inorganic ions was treated with sodium borohydride (0.25 g) for 24 hrs. The solution after removal of excess borohydride, was evaporated to dryness and the residue was distilled with methanol to make it free from borate ions. It was then hydrolysed with sulphuric acid (N, 10 ml) and the hydrolysate was worked up to a thin syrup which furnished spots corresponding to galactose, glycerol and glycolaldehyde when examined paper chromatographically (Solvent S_1, Spray reagent R_4). Resolution of a part of the syrup on Whatman No.3 MM sheets was carried out to obtain galactose and glycerol as individual components. Their estimations by phenol-sulphuric acid (Dubois, et al., 1956) and chromotropic acid (Lambert and Neish, 1950) reagent respectively showed their occurrence in a molar ratio of 1:1 approximately.

Methylation of A. occidentale gum and hydrolysis of the methylated product: *A. occidentale* gum (10 g) was methylated with sodium hydroxide and dimethyl sulphate in presence of dimethyl sulphoxide as solvent. Partially methylated product was treated with Purdee's reagent to yield the fully methylated compound (7.33 g) as a viscous liquid. Upon crystallization from acetone, it furnished fine needles, m.p. 190°, $-OCH_3$ – 33.99 per cent. Hydrolysis of the fully methylated product (5 g) was carried out successively with 72 and 12.5 per cent sulphuric acid as described earlier. The working up of the acid hydrolysate in the same manner gave rise to methylated uronic acid identified as 2,3,4-tri-o-methyl-D-galacturonic acid (yield 0.12 g) along with a mixture of methylated neutral sugar (yield 3.66 g). A quantitative partition chromatography of the mixture of methylated neutral sugar following the procedure described earlier led to isolation of six methylated sugars. Four of them, namely, 2,3,4,6–tetra–, 2,4,6–tri–, 2,3,4–tri- and 2,4–di-o-methyl galactoses were found to be identical in all respects with the same compounds isloated earlier as hydrolysis products of the methylated degraded gum. Characterisation of the remaining two new methylated neutral sugars has been done as follows:

1. 2,3,5–tri-o-methyl-L-arabinose (Rg 0.97 in S_1), $[\alpha] D^{28}+17°$ (c, 0.18 in chloroform) (Found: $-OCH_3$, 47.5; Tri-o-methyl arabinose, $C_8H_{16}O_5$, requires $-OCH_3$, 48.4%). Upon bromination and subsequent treatment with methanolic ammonia at 0° for 48 hrs. it furnished crystals of amide of 2,3,5-tri-o-methyl-L-arabonic acid, m.p. 136°. Cuneen and Smith (1948) reported a melting point of 136.7°.

2. 2,4-di-o-methyl-L-arabinose (Rg 0.64 in S_1), $[\alpha] D^{30} + 122°$ (c, 0.51 in water) (Found:– OCH_3, 34.8; di-o-methyl-arabinose, $C_7H_{14}O_5$, requires $-OCH_3$, 35.3%). It furnished a crystalline 2,4-di-o-methyl-N-phenyl-L-arabinosylamine, m.p. 144 – 6°. Jones (1953) reported a melting point of 145 – 6°.

Periodate oxidation of A. occidentale gum: Pure gum (0.58 g) was treated with an aqueous solution of sodium metaperiodate (0.15 M; 40 ml) and the volume of the resultant solution was made up to 250 ml. It was left in the dark at room temperature for 10 days and the periodate consumption and liberated formic acid were estimated at definite intervals of time. After completion of reaction, the consumption of periodate and the amount of formic acid produced were found to be 1.17 and 0.25 moles respectively per mole of anhydrohexose unit. Periodate oxidised gum on hydrolysis with acid furnished galactose only identified by paper chromatography.

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A Review of Quality Control and Pre-Shipment Inspection of Cashew Kernels

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Abstract

This review presents the details of enactment of Export (Quality Control & Inspection) Act, 1963; establishment of EIAs- taking over of scheme of Quality Control and Pre-shipment Inspection from CEPC; grade specifications notified by the Government of India; improvements brought in Vitapacking Machine; inculcation of personal hygiene; improved method of conditioning of kernels; regular anti-infestation and disinfestation measures; improved packing and adoption of good manufacturing practices. In addition, phenomenal growth of cashew industry during the past decade; increase in quality; increase in foreign exchange earnings; increase in unit value; how quality sustained the markets especially in the context of emergence of competitors; enhanced confidence of buyers; minimised complaints from abroad; sustained image of India as supplier of quality product are discussed. The need for continued surveillance to ensure product quality and the role of EIA officers in bringing about discipline in the processing industry and the resultant increase in productivity and quality, the most important factor in creating and retaining markets are detailed.

Introduction

The enactment of the Export (Quality Control and Inspection) Act in 1963 marked the India's efforts to ensure quality products to the buyers abroad. This Act brought Cashew Kernels, an important item of export, into the ambit of Compulsory Quality Control and Pre-shipment Inspection in 1964. To begin with, the scheme was operated by the Cashew Export Promotion Council and later when the Government of India established the Export Inspection Agencies in 1966 for the specialized function of quality control of export items the scheme was taken over by these Agencies.

Basis of inspection: The grade specifications recognized in the Export (Quality Control and Inspection) Rules, 1964 form the basis of inspection. The rules make it compulsory that all consignments of cashew kernels for export should be accompanied by a certificate of export worthiness issued by any of the Agencies established by the Government of India under Section 7 of the Export (Quality Control and Inspection) Act, 1963 to the effect that cashew kernels conform to the recognised specifications. The grade specifications have been drawn up in consultation with the representatives of the trade as well as other relevant organisations. The buyers requirements and the traditionally accepted norms have been the guiding points in evolving standard specifications. The specifications are dynamic and not static as they could be adopted to the changing consumer preferences. The Export Inspection Council has been laying great stress on this aspect which is highlighted by the introduction of new grades like W/180 and also the size-grading of Scorched Wholes grade.

Operation of the scheme: More than 15 years have passed since the scheme of compulsory quality control and pre-shipment inspection for cashew kernels was put into operation. Cashew Industry being highly labour oriented while it is low capital intensive, innovative ideas in processing operations could find implementation only through persistent persuasion. Prior to the introduction of quality control they did not realise the importance of the need for hygiene and sanitation and the necessity to adopt good manufacturing practices. The operation of the scheme over the past years had significantly helped in awakening the consciousness and creating the willingness for quality.

Improvements in the processing technology: Eventhough the primary function of Export Inspection Agency is end-product inspection, it has been emphasising the need to introduce innovative gadgets to increase the processing efficiency in order to improve quality. This has yielded encouraging results.

The Vitapacking machine: The Vitapacking Machine is the most critical instrument in the processing unit which ensures the hermetic condition in the containers guaranteeing the wholesomeness of the product till it reaches the buyer. Today all the units where filling and packing of cashew kernels for export take place, the Vitapacking Equipment is invariably installed. The officers of EIA during inspection visits, check up the efficiency of operation of the machine and whenever discrepancies are observed ensure prompt rectification.

Personal hygiene: The EIAs were assigned with the task of educating workers and supervisory personnel in the cashew processing industry on the necessity of personal hygiene. Campaigns have been organised to focus their attention on the various steps to be adopted to achieve these objective. Today the workers cleanse their hands and feet as a matter of habit before entering the processing hall each time. Chewing and smoking in the processing department is strictly forbidden. In the peeling, grading and filling sections, headgears are worn by the workers. Booklets have been published in the local languages by the EIAs outlining the guidelines on the control of infestation describing the anti-infestation and disinfestation drills to be followed by each processing unit.

Metallic wares in the processing departments: Bamboo baskets and winnows which were in use in the processing departments have now been replaced by seamless aluminium wares. Despite the high initial investment, the efficiency of the metallic wares in precluding insect harbourage coupled with the durability was driven home to the processors. Now in the organised sector, all the units have changed over to metallic wares in the peeling, grading and filling departments.

Pneumatic Foreign Matter Segregators (PFMS): The kernels at the filling tables may still contain fragments of testa and other foreign matter. An equipment known as 'Pneumatic Foreign Matter Segregator' was developed which aircleans the kernels to eliminate the extraneous matters. It has been proved to be quite efficient in performance and now at every cashew processing unit where filling is done, the PFMS has been installed at the filling table. The officers of the EIAs during their inspection make it a point to check up the working condition of the equipment.

Processing departments: Guidance from the code of good manufacturing practices for food processing industry has been of immense help in effecting improvements in the various processing departments. Bird proofing, shelling, peeling, grading, filling and packaging sections and providing canopy over the filling table as protection against insects falling into the kernels are a few of the measures adopted. Polythene laminates are now used as lining material for the receptacles in the grading and filling departments. Improved technology in the heat treatment of the unpeeled kernels and the conditioning of the kernels (a process through which optimum moisture level is ensured in the kernels to prevent breakage during filling, packing and transportation) can be reckoned as creditable achievements of the EIAs.

Technical guidance: The officers of the EIA, apart from assessing the level of hygiene and sanitation in the processing units, impart guidance on technical problems. Infestation problem has been a major area of attention. The attention of the processing personnel could be brought to the various focal points of infestation and critical areas in the processing line and prophylactic measures taken at the right time. Dissemination of information on the newer insecticides, the periodicity and dosage of their application, drawing up of schedule of operation as well as the frequency of insecticidal treatments have been the important extension functions of the EIA. The conspicuous impact was proved by the effective combating of the problem of infestation.

Improved packaging: The wooden cases which were in use often proved to be a source of infestation besides causing hazards to the men handling them. EIC could successfully initiate the change over from wooden cases to corrugated multi-ply cartons.

Collaborating with the Indian Institute of Packaging an indepth study was conducted by the EIC on the packaging requirements of cashew. In consonance with the recommendations which emerged out of the study, minimum requirements were stipulated for tin containers and cardboard cartons for packing cashew kernels for export. The relevant Government of India notification requires that tin containers shall be fabricated out of prime quality tin sheets of 30 SWG (0.315 mm) and each container shall weigh not less than 1 kg. The corrugated fibre board cartons used for packing shall be of 5 ply and shall have the minimum bursting strength of 12 kg/cm^2, the corrugating medium having a minimum substance of 150 g/m^2, combined weight of liners having minimum substance of 450 g/m^2 and puncture resistance of 175 beach units. Wooden cases are allowed today only when the buyers specifically indicate their option in the contracts and these are to be treated against insect infestation and shall be free from mould growth.

Notification on roasted & salted cashew kernels: Another important achievement is the introduction of Compulsory Quality Control and Pre-shipment Inspection for salted and roasted cashew kernels. This has been done taking into consideration the export potential of this item. Minimum requirements of preparation and packing including chemical standards have been laid down. The notification has been drawn up taking into view the variable packaging requirements of the buyers. Determination of rancidity through chemical tests vis-a-vis organoleptic evaluation has been stipulated as a confirmatory measure of the quality of the product.

Impact of quality control: Prior to the introduction of Compulsory Quality Control there had been literally floods of complaints from the buyers on the quality of the material reaching them from India. Today, after fifteen years of operation, one can find that complaints have become few and far between. Whenever any complaint arises, investigation is conducted promptly to identify the reasons and locate the lacunae if any so that remedial measures could be taken to prevent recurrence. There have been several problems confronting the industry like shortage of the raw material, emergence of competitors in the international markets eroding our monopolistic position, fluctuation of kernel prices and many others. In this complex situation, quality consistency remains as a silver lining in the clouds. Indian cashews have an image as a quality product and continue to retain it in international market which is an outcome of the ceaseless efforts taken by the EIA at several points.

Discussion

D.C. Russell: How do you reconcile the existance of your agency and the conditions of the factory reported by Dr. M.R.G.K. Nair in his paper in entomology session?

U.K. Unnikrishnan: Dr. M.R.G.K. Nair might have referred to the units in the unorganised sector. In the organised sector tremendous improvements have been brought about. We have drawn up a comprehensive programme known as the 'In-Processing Quality Control' when this programme is implemented it will statutorily prevent units in the unorganised sector from processing. We have drawn up the IPQC scheme taking into consideration the guidelines of the Codex Alimentatius Commission on Food Processing Unit. When the IPQC is implemented it will be the answer to the problem.

DEVELOPMENTAL PROGRAMMES AND MARKETING

Chairman : **K. V. AHAMED BAVAPPA**

Rapporteur : **L. KRISHNASWAMY**

Cashew Development Programme of FAO in the World

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This title would suggest that FAO has a world approach to the development of Cashew Production, Processing and Marketing and would plan its intervention according to an objective of so many hectares planted or so many tons of cashew nut produced in the next 5 or 10 years. This is not the case. Our activities are initiated by the requests received from Governments of developing countries interested in promoting a national cashew nut development scheme or more simply in improving yield recovery from existing processing plants.

The last 10 years have seen many countries becoming interested in developing a cashew programme from the already existing few hectares and small plots around villages. FAO was ready to help, since there are many reasons that speak in favour of this crop, such as:

— Marginal lands which are unsuitable for other crops can be utilized for cashew

— It can be grown in small plots by farmers and with simple but regular plant protection measures its yield increases well above 10 kg per tree

— It provides cash to the farmer, thus improving rural income

— Processing of cashew in the country provides employment and foreign exchange

Requests received from and assistance provided by FAO since 1979 covers particularly in West Africa, Senegal, Ivory Coast, Togo, Cameroun, Nigeria and in East Africa, Uganda, Tanzania, and Zambia. In Asia, Bangladesh and Sri Lanka and in Latin America, El Salvador and Colombia have asked for FAO assistance. Feasibility studies have been prepared for all countries of West Africa interested in cashew in the last 10 years, with sometimes a follow-up as in Benin, Nigeria and the Ivory Coast where processing plants have been installed.

Italians will concentrate on cashew entomology, phytopathology and vegetative propagation.

The World Bank has approved the extension of the project through 1979.

The FAO assistance in training consists generally of a tour to India and the Central Plantation Crops Research Institute in Kasaragod is to be thanked for having organized visits to factories and plantations for our FAO fellows. Study tours are also organized to Kenya and Tanzania to visit the various processing factories existing there.

The publication entitled "Cashew Nut Processing" (by D.C. Russell, a worldwide authority on Cashew nut Production and Processing and FAO consultant) was issued in 1969 as an Agricultural Services Bulletin No.6. In addition, each project or consultancy under FAO leads to a report to the Government with practical guidelines.

Production of cashew has to be considered in each country according to the existing social structure and present state of cashew production. While favouring an approach which should benefit the small farmers and create or increase income at the rural and village level (distribution of selected seeds, improved cultural and marketing practices), FAO is also aware of new plantation estates being established in Brazil for instance. We have to provide our technical assistance within the framework of the government's principles for development.

Secondly, the technology of cashew processing has developed rapidly from the small cottage industry into large somewhat sophisticated plants of 10,000 to 20,000 tons per annum. The choice of technology and equipment depends on the scale of operation. In Uganda where the harvested production of raw nuts was less than 50 tons in 1978, the census for 1977 reveals that some 100,000 cashew trees were surviving in 1977. Yet, the national programme target was fixed at 36,000 hectares planted in 1980 against 10,000 hectares said to be existing in 1975. Since, uncertainty prevailed as to achieving the national target and there are no processing facilities in Uganda at the moment, a 600 ton raw nut plant was selected. This is as far as FAO can go in the assistance to development. If production increases to a sufficient level of 5,000 tons for instance, a pre-investment oriented project might be prepared by FAO on request from the Government for submission to a Development Bank for financing. In Zambia, the Department of Agriculture operates a small home-made processing unit at Mongu, roasting 15 tons of raw nuts each year. FAO Assistance has been requested in order to prepare a plantation programme with selection/breeding and extension advise and a detailed economic study for submission to the

African Development Bank. Size of the plant and equipment will depend on this study. However, new processes are now beyond the development stage and have or will have in the next two years reached the industrial application thus giving a large range of choice and, perhaps, higher technical performances to the benefit of national investment programmes for cashew. FAO maintains close contact with experts and manufacturers and Research Institutes working on cashew processing, but does not finance research for a new technology.

In conclusion it is emphasised that successful study tours and seed selections imply multinational understanding and more precisely, technical co-operation among developing countries to help each other towards better income to farmers, workers and the countries themselves. It might be contradictory to existing competition on the world market for selling 320's or Fancy Butts when the market is as low as it is at the moment, and when due to machanization, our host country today, India, has to envisage a drastic change in its policy due to the significant reduction in quantities of raw nuts supplied from East Africa. It is the duty and interest of all to overcome immediate contradictions and work together towards a better world and a place under the sun for everyone.

Cashew Development Programme in India

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Introduction

Four centuries ago Portuguese settlers brought with them cashewnuts and planted mainly for purpose of checking soil erosion. The cashew crop spread to the Malabar and Konkan coast of India, later over the Coromandal coast and other parts. In the early stages it was the apple which was considered valuable because of its obvious attraction. India had to wait for three centuries to realise the value of the kernel inside the nut. Until the end of the second world war, exports were small indeed. But after the dawn of independence in 1947 the exports mounted up very rapidly. There was year to year progress in this direction and in 1949–50 the export stood at 19,277 tons valued at Rs. 56 millions and by 1974–75 it reached the peak figure of 65,025 tons value at Rs. 1181 millions.

India had been till recently making use of the rawnuts available in East African countries for two reasons: (1) those countries had no use for them otherwise than for export to India by which they were earning sizeable income: (2) fruiting and harvesting season in those countries which lie on the south of the equator are during the period August – October against February – April in India. This phenomenon enabled our country to collect the raw material so that they could work the factories spread over a longer period in the year. As the labour in the East African countries could not successfully carry out the processing operations which have been till recently entirely manual, the export of rawnuts by them to India was by itself a profitable business for them as otherwise they were lying unutilized and wasted. The situation has since changed as every country has to make the best use of its raw materials for its own benefit. India has been very well aware of this feature in international trade, having itself been subjected to exploitation as a colonial country by the Imperial power for too long. Rightly therefore, India had projected cashew development programmes for increasing the out put of the raw material within its own sources.

Programmes: The developmental programmes in cashew started in the Second Five Year Plan (1956 – 61) and were largely centered round expansion of area under cashew. The states in the southern peninsula were the chief centres of activity viz. Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, Goa, Orissa and West Bengal. Work during the Third Five Year Plan (1961–66) was continued on the same basis. Growers were encouraged to raise cashew in all possible ways in their homesteads, farmsteads, open areas etc. mostly the areas involved were rather poor and marginal soils. Better areas could not be made available as they were mainly used for other food and commercial crops. The yields of cashew also have not been such as to attract better attention and better areas. However, cashew promotion was sought to be achieved by inducing the growers to take interest in cashew by supply of improved and selected seed and quality planting materials, chiefly seedlings and also air-layers wherever possible and feasible. High yielding individual trees were spotted out in the existing plantations and seed materials were collected therefrom and distributed. Progressive states like Tamil Nadu gave long-term loans also to growers. This apart, the Government started cashew plantations in their own areas, especially in forests, river valleys and a sizeable area was built up over the years.

The research on cashew was centred round plant protection measures, N, P and K requirement and also introduction of improved methods of vegetative propagation. Accordingly production and distribution of air-layers, running of demonstration plots in grower's fields for the adoption of improved practices including fertilizers and plant protection measures and mass coverage of plant protection in selected areas were the chief developmental programmes during 60's. The Fourth Plan and the Fifth Plan witnessed increased activities on these lines. Brief notes on the technique of these schemes and other particulars are furnished in Appendix 1.

As a permanent measure to supply improved planting material to the growers, progeny orchards have been started during the Fifth Five Year Plan in the major cashew growing states with most promising hybrids evolved in the research stations and elite trees located in the private gardens and Government stations and also exotic types. Under the World Bank aided Kerala Agricultural Development Project efforts to locate a seed garden in Kerala are underway.

The impact of the developmental programmes is apparent from the area increase under cashew from 103,607 ha at the commencement of Second Five Year Plan to 417,296 ha by the end of 1977. Currently considering the need for intensifying cashew production in India, World Bank is financing a Multi-State Cashew Project to be operated in four southern states viz. Kerala, Karnataka, Andhra Pradesh and Orissa.

APPENDIX I

Brief particulars about the development schemes in India

A. Fourth Five Year Plan

1. *Centrally Sponsored Schemes*

(i) Scheme for laying out demonstration plots in *ryots*' holdings

(ii) Adoption of mass prophylactic plant protection measures in selected areas

(iii) Scheme for production and distribution of vegetatively propagated planting material

(iv) Scheme for special package programme in departmental areas

(v) Scheme for special area expansion programme in departmental areas

B. Fifth Five Year Plan

(i) Scheme for laying out demonstration plots in *ryots*' holdings

(ii) Scheme for improvement of cashew by vegetative propagation

(iii) Scheme for subsidised area expansion programme in departmental and non-departmental areas

(iv) Scheme for collection and distribution of pedigree cashew seeds in Andhra Pradesh

(v) Scheme for central participation in equity of the state level cashew development corporations

(vi) Scheme for establishment of progeny orchards for cashew

1. *Scheme for laying out demonstration plots in ryots' holdings:* This scheme has its objective to educate and convince the growers about the need for scientific management practices for cashew trees. Each such plot will be of 0.8 hectare. The practices demonstrated include (1) application of fertilizers at 250 g of N, 150 g of P_2O_5 and 150 g of K_2O per adult tree and (2) adoption of plant protection measures against pests and diseases. The inputs will be supplied to the growers free of cost. There will be a controlled plot where no such treatment will be applied. Yields of the treated and untreated plots will be compared.

2. *Scheme for improvement of cashew by vegetative propagation :* The Scheme is intended to stabilize the yields of cashew by resorting to vegetatively propagate the high yielding individual trees located in the research

stations and private gardens and also the hybrids evolved at the research stations. Since grafting, veneer grafting and patch budding have been found to be useful, a programme for a fairly large coverage adopting these techniques has been proposed under the scheme.

3. *Scheme for the establishment of progeny orchards:* To meet the increasing demand for quality planting materials, a chain of progeny orchards planted with high yielding selections and hybrids in the different states of the country has been proposed under the scheme. This will be raised under scientific management including timely plant protection measures and application of fertilizers.

4. *Scheme for subsidised area expansion programme:* This scheme is intended to give financial assistance by way of subsidy to the growers, both private and Government. The subsidy of Rs. 300 per hectare has been proposed for private growers and Rs. 500 per ha. for departmental areas. This will be distributed in kind (planting materials, fertilizers and plant protection chemicals) during the first two years of planting.

5. *Scheme for central participation in equity of the state level cashew development Corporations:* Under this scheme, it is proposed to associate Central Government with the State Cashew Development Corporations by participation in their equity in the ratio of 49:51, thus by way of giving encouragement to the State Corporations.

All the above schemes are directly financed by the Central Government and implemented through the co-ordinating agency viz. the Directorate of Cashewnut Development located at Cochin in Kerala state.

Discussion

K.R. Choudry: The investment on research on cashew is too small when compared with the felt need for research effort, the amount of foreign exchange cashew earns should also be taken into account in this regard.

N.M. Nayar: India has been spending over Rs. 15 lakhs annually since 1971 on cashew R and D work. This will be more than doubled from 1979–80. There is an urgent need to increase the research efforts, but the main bottlenecks are the shortage of sufficiently qualified scientists and good research programmes and not funds.

ARDC Finance for Cashew Development

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The Agricultural Refinance and Development Corporation (ARDC) has been in the field of refinancing agricultural development programmes during the last 15 years. Amongst the various purposes of development, plantation crops including cashew are eligible for refinance.

The main object of ARDC is to assist the proposals in respect of various agricultural development projects which normally need a medium or long-term assistance. The refinance is available through co-operative and scheduled commercial banks. In respect of plantation crops, new planting, re-planting and rehabilitation wherever there is a definite gestation period or the initial investment is quite large qualify for ARDC assistance. Infrastructural facilities required such as development of irrigation facilities, land development and fencing, laying of farm roads, construction of storage buildings and labour houses and transport vehicles required for efficient running of the farm are also refinanced if the scheme is an integrated one. Assistance for processing arrangements of the produce is considered if it is combined with production.

The projects should be self-generating and the income adequate enough to facilitate the liquidation of loan within 15 years. While the repayment has to be made from the profits accruing from the developmental activity undertaken, the interest on the principal is required to be paid annually (from the second year) except in deserving cases where it could be deferred.

The other objectives of ARDC are (i) to bring about diversification of purposes of development, (ii) development in nontraditional areas where potential exists, (iii) reduce regional imbalances in development and (iv) laying stress on the needs of the small farmers.

There is a general misconception that the ARDC is only a financing institution. Though it does deal with credit requirement, the ultimate aim s to achieve the desired development in the concerned field. Accordingly the feasibility of the schemes both from the technical and economic view points is looked into. ARDC would like to ensure that developmental projects envisaged are basically sound and are operated with adoption of package of the improved recommended practices. The developmental activity has to run on commercial lines. To this effect various technical and economic norms are prescribed.

In order to keep a track of the progress of the schemes evaluation, studies are undertaken at various stages to ensure that the performance and progress are taking place along the right lines and to remove the bottlenecks if any that may have been confronted during such studies.

Promotional activities are also undertaken to guage the potential for development in particular areas by undertaking pre-investment studies and surveys.

Perspective planning is done taking into consideration the various developmental plans of the Central and State Governments and carrying out a detailed exercises in respect of the likely requirements.

The cashew is one of the important plantation crops which has come in for ARDC refinance during the last five years. During this period 15 cashew development schemes have been sanctioned with a financial assistance of Rs. 540 lakhs and a commitment of Rs. 280 lakhs upto the end of financial year 1977–78 of which Rs. 14 lakhs have been disbursed so far. In addition during the year 1978–79 the assistance committed by ARDC has been of the order of Rs. 195 lakhs.

The performance so far in terms of financial assistance for cashew forms only 3 per cent of the total commitment for all the plantation crops put together. The plantation and horticultural schemes in turn form 2.8 per cent of our total disbursements of over Rs. 1000 crores upto June 1978. ARDC is very anxious to take a breakthrough in plantation development in general and cashew development in particular.

The efforts of ARDC have resulted in the sanctioning of the Kerala Agricultural Project with a total lending programme of Rs. 80 crores for plantation development including Rs. 15 crores for cashew. Another cashew project is likely to be launched shortly with an outlay of Rs. 4000 crores benefitting an area of about 80,000 ha.

In the perspective planning for the next period 1978–83 the total programme identified as feasible is for an assistance of Rs. 2695 crores based on a natural growth rate of 25 per cent in its disbursement level. The share of plantation is expected to be about Rs. 94.5 crores. There is therefore no dearth of credit for the developmental projects on plantation crops along with cashew. The concerned organisations may take steps to identify the projects and approach the Banks.

Development in Cashew Cultivation and Research in Kenya

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Abstract

The Republic of Kenya has tremendous topographical diversity. Over 36,000 hectares were planted with cashew giving an annual production from 20,000 to 25,000 tons of nuts. One modern factory with a capacity of 15,000 tons is operational and another one is proposed — both in the coastal area of Kenya. In the initial selection programmes isolated trees yielding about 15 kg/tree/year, which is nearly doubling the farmers yield were identified. Other methods envisaged for yield improvement include selection from a broader genetic base, vegetative propagation and germplasm introduction leading to progeny testing as a long term programme. If intercropping is encouraged cashew trees could benefit from the residual effect of fertilizers applied to the intercrop. It is also indicated that the farmers could increase profitability on cashew growing areas by grazing (milk) cows under cashew on natural/sown pastures. The major pest/disease problems in Kenya, in addition to *Helopeltis* sp., is *Pseudotheraptus wayii* (coconut bug) which initiates the cashew shoot 'die back' – a disease made serious by secondary infection of fungi. For these pests chemical control in young trees is advocated.

Introduction

In Kenya cashew is grown mainly in the Coast Province. The soils are sandy with good drainage. The rainfall ranges between 500 mm to over 1200 mm per year. The crop thrives best at elevations from sea level to about 600 metres above MSL in the Kilifi, Kwale and Lamu districts of Coast Province.

Cashewnuts are among the oldest cash crops in Kenya. The cashew appears to flourish in poorer soils where other crops do not thrive. It was introduced into East Africa by the Portuguese during the 16th century. The Swahili name for the tree is "Mkanju" while the nut is "korosho" and the fruit is "kanju".

The processing of cashewnuts started in a small way in 1930 with roasting and cracking nuts under mango trees. By 1935 after a visit to India a type of drum roaster was introduced where shelling, peeling and grading was done by hand. In 1975 a modern factory covering an area of over 22,000 m^2 and capable of processing 15,000 tons was constructed.

Culture

In Kenya there are no specific plantations as such and the crop is grown and managed as small holdings. Traditionally planting is by seed selected from vigorous high yielding regular bearing and healthy plants. Generally three seeds per pit are planted directly in the field at 12 x 12 m apart. Pruning is recommended after one year by:

(i) removing lower branches on trunk and shape the tree

(ii) remove branches which touch the ground to prevent "bushyness" and avoid tsetse fly breeding sites

(iii) remove lower branches to enable animals to graze under cashew and possibly allow cultivation machinery to pass through

The coastal sandy soils are shallow and deficient in nutrients especially phosphorus. Application of Fe-chelates to seedlings propagated in plastic containers has proved beneficial before transplanting but no work on macronutrients has been undertaken so far. As such there is no fertilizer recommendation for cashew in Kenya. It is however a common practice among the farmers to apply manure around the trees and some do even use nitrogenous fertilizers especially during the short rains (Sept.–Oct.). If intercropping is encouraged the cashew could benefit from the residual effects of fertilizers applied to the intercrop.

In Kenya cashew starts bearing in 3–4 years. Flowering commences from August onwards in waves and so harvesting is spread over 3–4 months beginning in November.

Apart from basin weeding, clearing grass beneath trees up to the drip circle facilitates picking fallen nuts.

Production

There is tremendous variation in yields of cashew. Average yield is usually 6 – 7 kg/tree/year, however some trees may not give any yield in a year (Table 1).

The yield distribution indicate that the logical beginning for cashew improvement programmes in Kenya would be selection of high yielding trees and their vegetative multiplication. The clones so established will then be tested for their genetic ability to yield. If clones cannot be established, the same outstanding trees should be progeny tested, after crossing with tester parents.

TABLE 1. **Distribution of Yield in Unselected Trees**

No. of trees	*% of trees*	*Yield (kg/tree)*
54	34.0	0
72	45.0	1 - 9
16	10.0	10 - 19
12	7.5	20 - 29
2	1.2	30 - 39
3	1.8	50 - 59
1	0.6	100 - 119

In Kenya production is limited to the coastal belt (10 - 29 km wide) where the crop covers over 36,000 hectares. The present production is estimated between 20,000 to 25,000 tons per year.

One of the limiting factors in cashew production in Kenya is the low yields obtained in farmers' fields. Generally farmers get an average of about 8 kg per tree/year, and this does not encourage farmers to improve their management of the trees. In order to improve the productivity some studies were conducted at CARS on the productivity of cashew-animal-pasture complex. With an improved standard of husbandry, exotic breeds were kept grazing natural grass under cashews for the period of study. It was concluded that the association was a very viable economic proposition to the coastal farmer and that the results obtained from statistical trials could be repeated in commercial practice.

Research

Cashew selection/breeding programme: Selection of high yielding trees has been carried out at CARS farm for some time now and trees capable of producing about 15 kg per tree per year were identified. In order to obtain a wider base of genetic material the selection programme has been extended to cover the major coastal areas growing cashew (Kwale, Kilifi, Lamu, and Mombasa Districts).

Vegetative propagation: In 1969 work at CARS started on testing different methods of vegetative propagation. Side grafting technique has shown promising results at CARS. The usefulness of side grafting and patch budding methods however has been limited by the difficulty of raising suitable seedlings/rootstocks. Another problem faced was the possibility of disease/micronutrient problem on seedling rootstocks. Fungicides and micronutrient (Fe-chelate) administration however reduced the problem.

Pests and Diseases: There are four major pests prevalent on cashew trees.

(i) *Helopeltis anarcardii* feeds on the young stems, leaves and fruits causing permanent brownish-black lesions on the tissues. It is widely distributed in cashew growing areas of the coast and was reported in the late sixtes and early seventies as a major pest.

(ii) *Pseudotheraptus wayii* a serious pest of coconut has been observed feeding and even suspected of breeding on fruits of mango, guava and cashew.

Biology and feeding behaviour of both these pests have been studied. Laboratory breeding of *Helopeltis* has however proved difficult and effort to establish the relative importance of both insects has thus been hampered. An investigation on *P. wayii* however has indicated and confirmed that the bug can cause shoot damage – a symptom commonly described as 'die-back" even in the absence of *Helopeltis*.

No effort has been made to investigate biological control of the above insects. Since cashew trees at the Kenya Coast do not yield a high cash return per hectare, expensive spray programmes are not yet recommended to the farmers. It is, however, advisable to practice plant protection measures for young trees.

(iii) Other pests of cashew are the cashewnut weevil (*Mecocorynus loripes*) and the cashewnut stem girdler (*Paranaleptes reticulata*). Due to the slow rate of spread and reproduction in these pests damage can be controlled without the use of chemicals by cultural practices except possibly in young plantations where damage can be lethal to the trees.

Acknowledgement

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Discussion

C.K.G. Nair: Which are the chemicals used in Kenya for the control of *Helopeltis* and die-back disease.

C.M. Warui: Chemicals are advocated by Department of Agriculture but very few farmers, if any, used them, for control of *Helopeltis* and *P. wayii*. At present malathion (2%) is used for control of *Helopeltis*. Experiments to screen other insecticides/fungicides and cocktails of these available in our market are proposed. Cultural practices however are at present advocated for control of minor pests.

C.C. Abraham: *Pseudotheraptus wayii* is reported to cause nut crinkling in coconuts. Have you observed nut crinkling symptoms in cashewnuts in Kenya?

C.M. Warui: *P. wayii* has been recorded as a pest of coconuts causing not only nut cracking but nut abortion during early production. We have observed *P. wayii* feeding on growing shoots, nuts and even the apple especially during early development of the nuts. Damaged nuts/apples show characteristic crinkling symptoms and reduced growth. Secondary infection of fungi complicates the damage.

Cashew Cultivation and Research in Malaysia

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Abstract

Cashew (*Anacardium occidentale*) is being grown extensively along the east coast of West Malaysia on sandy bris soil where other forms of agriculture has not been able to establish itself. It is estimated that 3500 hectares are planted with cashew. The factors limiting the yields are (i) the poor fertility of the bris soil, (ii) climate of the east coast (iii) shortage of harvesters at the peak fruiting seasons. Agencies such as CIMA, MARDI and Department of Agriculture and Universities are conducting research to solve some of the basic problems.

Introduction

Malaysia is basically an agricultural country. The Government is very critical of any agricultural policy as it may affect the economy of the country. Recently the government embarked on crop diversification programmes. New jungle areas are being cleared for the growing both tropical and temperate crops. The extensive area of bris soil which is unsuitable for many agricultural crops had been utilised for the growing of cashew with an objective to improve foreign exchange earnings and to generate additional employment through cashew based cottage industries.

The potential for development of cashewnut industry had been investigated (Sedky, 1972). Cashew is being grown on bris soil in the east coast of Peninsular Malaysia (148,000 ha) and in Sabah (50,000 ha) (Fig.1).

Since its introduction into Malaysia hybridization programmes were taken up and today a few promising clones viz. C 11 and F 379 are available. The cultivation of cashew could be categorized as (a) unsubsidized crop, (b) subsidized crop and (c) commercial venture.

Unsubsidized crop: The cashew cultivation in homestead is considered under this category. The number of plants are limited by the available land space and the produce is primarily for home consumption. Practically, very

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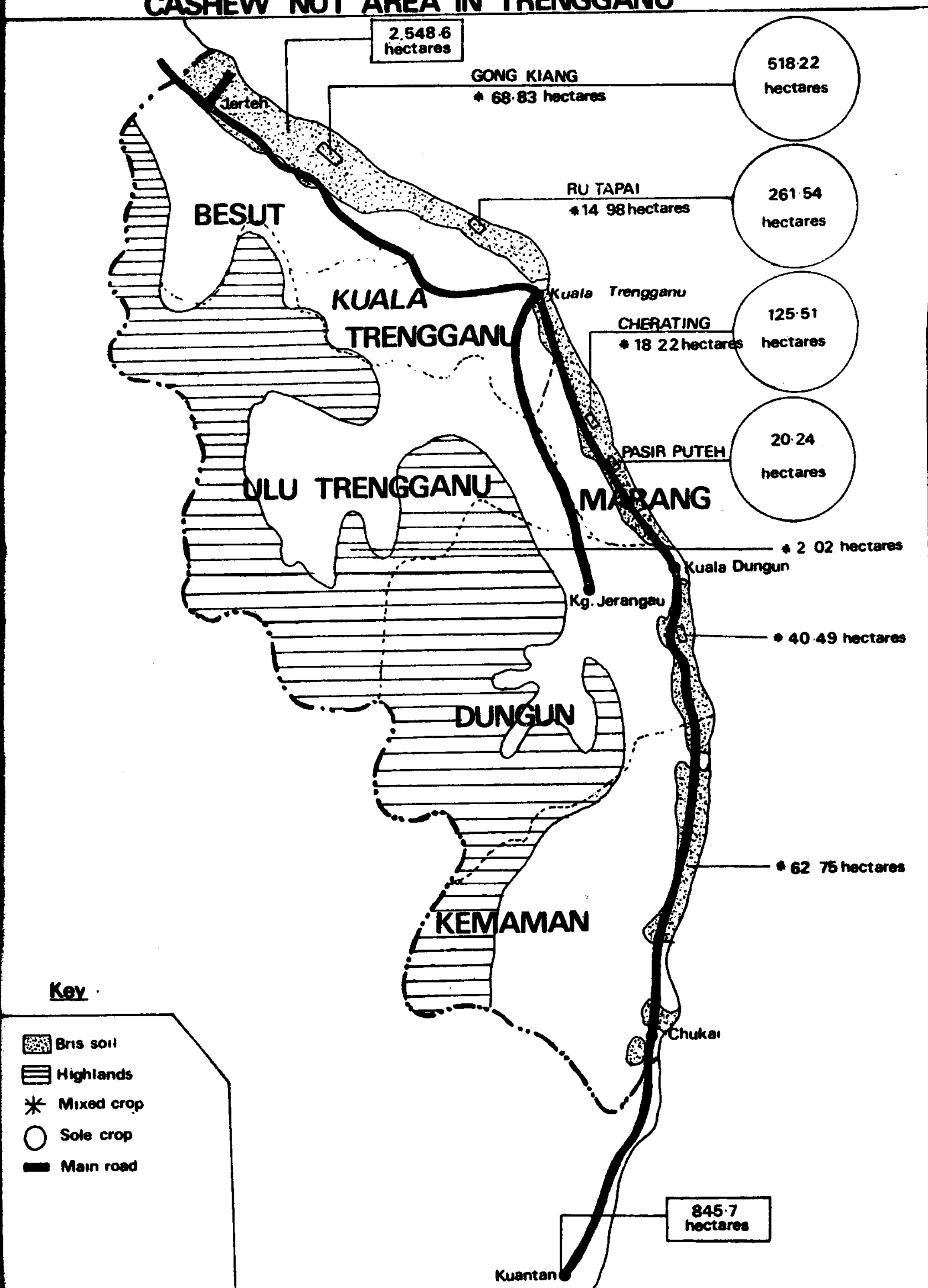
CASHEW NUT AREA IN TRENGGANU



little agronomic practices such as pruning, manuring and crop protection are being done. The yield of nuts is unpredictable.

Subsidized crop: In early 1963, the Malaysian Government initiated a subsidy scheme for the growing of cashew which was further intensified during the first Malaysian Plan, 1966–1970. The scheme was operated by the Department of Agriculture and the small holders are benefited through the supply of proven planting materials, fertilizers and the advice given by the agricultural officials. Besides, the above scheme also covered the vacant State land for cashew growing. A case study in the State of Trengganu showed that the Government spent M$ 101,188.77 from 1963–1970 for the subsidy scheme. It is assumed that the State Department of Agriculture has obtained about M $1.0 million for the development of cashew scheme in the Third Malaysian Plan.

Normally, the small-holder obtained an yield of about 400 kg/ha which depends on the cultural practices and management. Due to improper processing it is estimated that the cashew are retailed about 1/3 of their actual market values.

Commercial venture: In 1971, CIMA was set up to initiate a systematic programme of development of cashew in Malaysia. The cashew industry was confined to the bris soil of Peninsular Malaysia. An area ca. 4,000 ha had been allocated for the project. Plants had been set for processing the kernel and Cashew Nut Shell Liquid (CNSL), and due to shortage of raw nuts CIMA imported them from overseas for processing. The processed cashew is graded and grades I and II which account for about 30 per cent are exported to Germany. Grade III and the broken chips (70%) are marketed for local consumption. The CNSL is exported to Japan.

The cultivation of cashew had given rise to many technical and management problems detailed below:

1. Heterozygous planting material obtained from diversified sources resulted in wide variation in yield, productivity and gorwth
2. Maintenance, weed control, fertilizer application, protection from pests and diseases which are inadequate or neglected completely has in certain cases lead to the complete/partial abandonment of planted acreage before attaining productive age. To make the matters worse spontaneous fire hazards were common on bris soil
3. The crude procedure of cracking, drying, processing and packing of kernels resulted in relatively low market value
4. The climatic factors such as the monsoon in east coast of Peninsular Malaysia from Nov. – Jan. hampers the development of cashew

Research

There are various agencies such as Malaysian Agricultural Research and Development Institute (MARDI), CIMA and the Universities which are actively concerned with cashew growing problems and research. In the past year, these research agencies conducted their field trials independently and the trend to-day is to have joint research so as to prevent duplication of work. For instance, CIMA is working closely with Agricultural University of Malaysia for the research on pests and diseases of cashew. On the whole, the research activities can be categorised as:

(1) Planting materials/spacing (2) Soil management, (3) Yield and processing.

Planting materials/spacing: Many agencies are involved in this aspect of research. The research at MARDI on evaluation of promising clones showed that clone C 11 was the best yielder with 1331 nuts/tree, followed by clone F 379 with 943 nuts/tree (MARDI, 1977). Efforts are in progress to propagate vegetatively clone C 11 for distribution to the farmers. In addition to MARDI, CIMA is also carrying out exercise in identification of heavy bearing trees for their vegetative propagation and cross-breeding.

MARDI in 1974 had conducted an experiment to compare spacing 4.5 m x 4.5 m, 7.5 m x 7.5 m and two planting patterns i.e. square and triangle. The result indicated that close spacing gave better nut production per unit area (MARDI, 1977). It is possible to have a close planting at initial stage because thinning could be carried out later. CIMA is also conducting research to determine the optimum spacing for cashew. The density ranges from 179 to 358 plants/ha.

Soil management: Leaching of nutrients is one of the problems in application of fertilizers to cashew grown on bris soils. The research findings show that under proper management and adequate fertilizer application, cashew can come to bearing at an age of two years (Teo, 1977). Cashew like any other plant requires a proper nutrient balance of N, P and K and deficiences have shown characteristic symptoms (Teo, Kho and Thamboo, 1977). It was observed that increasing the nitrogen application improved vegetative growth and nut yield. There was no response to K application but cashew responded well to magnesium fertilization (MARDI, 1977).

Based on studies on time and frequency of fertilizer application, manuring before monsoon i.e. August to September in the east coast (De Geus, 1973) and split application of fertilizers are recommended.

MARDI and CIMA have few trials in progress to evaluate micronutrient needs using Mn, Cu, Zn, and B. In order to determine the optimal fertilization programmes foliar analysis of the nutrients has been attempted. A much more concerted effort along this line will be developed.

The importance of organic manures had long been recognised in the bris soil. Even though preliminary studies were encouraging, trials using soil conditioners such as bituminous material improved much the vegetative growth of the cashew, the beneficial effect was only observed at the initial stage. In the later years of crop growth there was no significant difference.

The bris soil could further be improved using legume crops, the potential use of *Cajanus cajan* has been reported. Besides legumes, guinea grass has been found to thrive well under mature cashew areas. Therefore, integrated farming by introducing livestock into cashew areas established with pastures or legumes is possible in bris soil (Teo, Kho and Thamboo, 1977). However, further research is necessary to determine the cost benefits of the projects.

Yield and processing: Chai (1974) reported that yield varies from 0 - 2363 nuts (15.0 kg)/tree/year. CIMA in their harvesting analysis showed that the yield obtained was ca. 40 kg/ha. The low yield could also be attributed to the trees which are just coming into bearing (4 years old). The yield could be further improved by systematic spraying with cocktail mixtures (insecticides + fungicides + foliar fertilizer) at the onset of flowering. Further research is necessary to determine the economics of the spraying programme.

The nuts are dried before they are processed. Preliminary studies showed that using polythene to cover the harvested nuts, has reduced the labour cost and saved considerable time. About two to three days was reported adequate for reducing the moisture of the nuts to 10 per cent. It was also observed that upto two years nuts could be stored with a moisture content of 13 per cent. The cashew apple has both astringent and acrid taste. Because of the lesser tannin the apples of local variety are popular as food in Trengganu and Kelantan than the Indian varieties (Sedky, 1972).

Preliminary trials at University of Agriculture, Malaysia indicated that wine preparation is feasible using cashew apple.

Many agencies such as MARDI, CIMA and Universities which are actively involved in cashew had conducted basic research to solve some of the urgent problems.

Acknowledgement

The authors wish to thank Dr. Hashim Abdul Wahab, Assistant Director of MARDI for his assistance in the preparation of this paper and also to FIMA agency for its co-operation in the publication of this paper.

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Discussion:

K.R. Choudry: Cashew is being grown on bris soils of east coast of Malaysia. Will you please tell us whether cashew cultivation is profitable vis-a-vis other perennial crops?

I. Abdul Ghani: Cashew is being grown on bris soil which is very poor soil. It is not suitable for other crops. However, crops such as tobacco and pineapple have thrived well on bris soils.

G. Obilisami: What are the legumes you are growing to improve the fertility of bris soils where cashew is cultivated?

I. Abdul Ghani: *Cajanus cajan, Stylosanthes gracilis, Centrosema sp.* and groundnut are doing well on bris soils.

Cashew Development Programmes of the Department of Agriculture, Malaysia

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Cashew was brought by Portuguese into Malaysia more than a century ago. Eventhough it can grow very well with little attention still is not being grown on large scale.

Cashew cultivation has been concentrated mostly along the east coast of west Malaysia on highly leached bris soil of marine origin. These are excessively drained, poor structured soil occuring over a narrow ridge running prallel to the coast line. Considering the fact that bris soils are suitable for cashew, the Malaysian government started cashew research programmes in 1952. At present an area of 6100 ha is under cashew cultivation in Malaysia.

Under the second Malayan Plan (1960–1965) and the first Malaysian Plan (1966–1970) the Federal Government had sanctioned funds for the development of cashew cultivation (Table 1).

Under the first Malaysian Plan, a two-pronged approach namely the planting vacant State land and the subsidizing small holders to grow cashew in their land was initiated. The response of the farmers to the scheme was not very encouraging due to the then prevailing notion that cashew is not an economical crop and it is prone to fire damage during dry seasons.

Under the Second Malaysian Plan the New Economic Policy of the Government was introduced with an objective of eradication of poverty through increasing opportunities for intersectoral movement from low productivity to higher productivity activities. The state Department of Agriculture had introduced cashew and paddy cultivation for the fishermen and farmers living along the coast. The State Government and the Federal Government will provide land and finance. The project is to be operated on a group basis with the supervision and aids given by the Department of Agriculture. Under the project 'Cashew for the Fishermen' the government had planted 95 ha in 1977 and 213 ha in 1978. The area for 1979 and 1980 are 206 ha and 270 ha respectively. The Department of Agriculture will manage the planting and when the trees start bearing the govern-

TABLE 1. **Government Expenditure on Cashew Development Programme**

Year	Area planted (ha)	Expenditure (M$)	
		Federal	State
1963	77	5741.3	..
1964	—	2968.1	..
1965	116	3279.9	..
1966	165	11397.0	4996.9
1967	116	12879.0	4769.2
1968	151	16989.2	3558.0
1969	152	19940.0	4956.0
1970	160	24994.3	3896.0

Source: Department of Agriculture, Malaysia.

ment will distribute the land to the fishermen and those farmers nearby at about 1.6 ha per family. These families will pay the development cost from the returns obtained from cashew. The payback period will vary depending on the development cost and the yield obtained.

Besides the Cashew for the Fishermen, the Department of Agriculture also has plots for demonstration and research purposes. In addition the Department of Agriculture and other agencies such as Cashew Industry of Malaysia (CIMA) had planted about 2800 ha and was able to put up the first cashew processing factory of Malaysia in 1978.

Discussion:

M.D. Mahadev: In Malaysia good forest land is being cleared and cashew is introduced as monoculture. Is this a good policy as the natural balance in ecological, biotic and edapic factors will be drastically retogressed.

Azmi Bin Moktar: Bris forests are not good forests since the trees are small and bushy. We do not plant cashew on good forest land. Instead, we plant oil palm and rubber. We do some replanting in forest.

Prospects for Cashew Cultivation in Suriname

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Suriname is an independent democratic republic, situtated in the north of South America between 2° and 6° north latitude and 54° and 58° west latitude. It has a small cosmopolitan population of around 35,000 most of the people living around the city of Paramaribo.

The climate of Suriname is generally humid and tropical. There are four seasons based on the rainfall distribution, a long rainy season from April to August/September, a long dry season from August/September to mid November, a short rainy season from mid November to mid February and a short dry season from mid February to April (Table 1).

These seasons are highly variable and in some years the short rainy season or the short dry season does not occur, although the long rainy and the long dry seasons are always encountered. The mean annual temperature is almost the same for the whole country and averages about 27°C.

Cashew plant thrives better in its adopted homes of India, Sri Lanka and Africa, than in its natural habitat. A significant feature in the vegetation of the Amazonian region, is the occurrence of many wild species of *Anacardium* which could be of economic significance in the future.

Among the wild species of *Anacardium,* a variety that is prominently seen in Suriname is, *Anacardium giganteum.* This variety holds good prospects for the future, as a source of genetic material in view of the fact that the large apple could be utilized in the prêparation of delicious beverages as well as potent alcoholic beverage.

In Suriname, scientific experiments for the growing of cashew, were undertaken only in recent years. Experimentation was undertaken at Coebiti and at Brokkobakka. Seedling material was obtained from diverse sources such as, from India, Tanganika, Sri Lanka, Mozambique and Jamaica with the objective of obtaining information on the adaptability of the cultivars to thrive under untreated conditions in Suriname. The introductions were planted in June 1974.

The yields obtained for two years from the Brokkobakka plot are presented in table 2.

TABLE 1. **Total Rainfall – Paramaribo 1901 – 1966**

Period	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Annual*
1901 – 1930	187.7	144.1	181.6	233.3	309.4	312.4	249.0	161.6	80.3	85.4	124.9	219.9	2289.6
1931 – 1960	192.9	150.0	162.2	231.9	321.0	302.7	225.6	166.8	85.9	86.7	108.6	173.9	2208.2
1961 – 1966	186.6	143.5	162.2	219.3	306.9	309.9	332.3	164.6	81.2	87.0	116.1	192.8	2202.4

TABLE 2. **Yield Data of Cashew from Experimental Plot BR 20 (Brokkobakka) – Planted in 1974**

			1976			1977		
Country of origin	*Acc. No.*	*No. of plants*	*No. of fruits*	*Wieght of fruits (g)*	*Production per plant*	*No. of fruits*	*Weight of fruits (g)*	*Production per plant*
Sri Lanka	AC 10	46	..	..	..	191	1037	259
Tanganika	ATA 19	254	3071	19278	3856	3776	25397	5079
Malaya	AM 12	341	1834	10307	2577	4683	24626	6156
Sri Lanka	AC 1	196	679	6350	1587	741	5571	1392
India	AIN 64	419	2977	13562	4520	5968	28618	7154
Mozambique	AMOZ 27	429	1197	5833	1948	2465	12061	2412
	Mixed	148	142	1235	205	84	690	86

As the plots were untreated infestation occurred in the experimentation plot at Coebiti during July 1978. A careful observation of the symptoms developed such as the blossom blight, blackening and die back of the cashew plant, indicated the occurrence of the insect pest, *Helopeltis antonii* which is commonly referred to as the tea mosquito in India. It is now possible to bring about successful insect control measures, coupled with appropriate fertilizer application, so that better yields under treated conditions could be obtained.

It will be observed that the yields obtained under untreated conditions were very satisfactory and the second phase of experimentation may well establish cashew as a useful cash crop for Suriname.

The land in Suriname do not seem to be a limiting factor for growing cashew. There are extensive areas of sandy waste land as well as coastal areas which could well prove to be potential areas for the growing of cashew.

The climate of Suriname has its own characteristic features and is marked by the lack of well defined seasons. Due to the erratic nature of wet and dry days, cash crops such as cashew and mango flower throughout the year, and various stages of blossoming and fruit formation are observed at a time leading to practical difficulties in carrying out pest control measures. Nevertheless, well balanced economic scientific practices could bring about any entomological and pathological problems under control.

Presently some of the entomological problems encountered in the growing of cashew in Suriname is adequately handled by the scientists and foreign consultants at the Central Agricultural Experimental Station at Paramaribo, while the pathological problems are now closely investigated by the biologists of the Faculty of Natural Resources of the University of Suriname.

The lack of labour is a serious drawback for any type of cultivation in Suriname. The only answer to this problem is mechanisation whether it be partial or complete. Further, simple processing practices such as roasting and decortication, as done in the households of India, Sri Lanka and Africa, are unknown in Suriname. Some education in modern processing practices and in the commercial importance of the nut and apple, could reverse this unfortunate situation.

The future of cashew cultivation in Suriname as a viable commercial crop will be dependent on the following:

1. The formulation and adoption of successful plant protection measures under the prevailing climatic conditions of Suriname

2. The use of mechanised operations for the collection and processing of cashew

3. The exploitation of the potential of the wild varieties of *Anacardium* which appears to thrive better under Suriname conditions

4. Integration of the by-product development with the main industry

Acknowledgement

I wish to thank Dr. Ir. J. Ruinard, Dean, Faculty of Natural Resources for his encouragement Mr. F. W. van Amson, Director, Agricultural Experimental Station for valuable information and Dr. A.H. Dijk, Director, Stitching Experimentele Landbouwbedrijven (Foundation for Agricultural Experimentals) for his interest in the subject and finally the Indian Council of Agricultural Research/Commonwealth foundation for sponsoring my trip to India.

Marketing Trends in Cashew

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Introduction

India is the largest producer of raw cashewnuts and the exporter of cashew kernels in the world. Right from its inception, this industry is mainly export-oriented and highly labour intensive and more than two lakh labourers are employed in the organised sector in the industry in different states. India has been holding the monopolistic position in the supply of cashew kernels in the international market till recently while persistently relying upon the imported raw nuts from East African countries.

Cashew gained commercial importance when shipments of cashewnut kernels commenced from India during the first quarter of the present century. Since then the export trade has developed phenominally. The annual export of cashew kernels from India ranged between 50,000 to 66,000 tons in the past decade except for the year 1977–78. About two-third of the processed nuts were imported till the year 1973–74. From 1974–75 onwards the percentage component of the indigenous nuts which entered in the export trade has been increasing (Table 1). The export of cashew kernels from India has grown at the rate of 4.1 per cent per annum during the period 1947–78 as compared to the annual growth rate of 6.6 per cent of the world export. The component of indigenous production in export trade has grown comparatively at a slow rate of 3 per cent per annum during the above period. The elasticity of the cashew kernels exported from India with reference to the indigenous component in export trade has turned out to be 1.36 and the elasticity with reference to the total export in the world is much below unity (0.62). It is evident therefore that Indian export has been growing faster than the Indian production but lagging behind the world export. Now there is an increasing recognition for an efficient marketing system for accelerating the production of cashew and for exporting the cashew kernels from India.

Marketing and pricing policy: Marketing of raw cashew in our country has not yet been organized in the systematic manner except in Kerala. As per the present practice in vogue, a major portion of the produce is collected by itinerant merchants and the agents of producing units, who during the

TABLE 1. **Imports of Raw Cashewnuts into India and Exports of Cashew Kernels from India**

Year	*Export of Cashew Kernels*		*Rawnuts Equivalent at 24% of recovery in tons*	*Import of Rawnut*		*Component of indigenous production in tons*	*Percentage of indigenous production entered in Export*
	Quantity in tons	*Value in Rs. (000)*		*Quantity in tons*	*Value in Rs.(000)*		
1950 – 51	26307	85510	101279	54819	28456	46460	45.87
1955 – 56	31359	129246	130663	63154	48372	67509	51.67
1960 – 61	43625	189130	181771	118321	26082	63450	34.91
1965 – 66	51267	273996	213613	160636	150603	52978	24.80
1970 – 71	50284	520568	209516	169359	294076	40157	19.17
1971 – 72	60378	613321	251575	169985	279060	81590	32.43
1972 – 73	66278	688214	276158	197938	318093	78220	28.32
1973 – 74	52293	744322	217887	150249	287986	67638	31.04
1974 – 75	65025	1181373	270937	160358	366043	110579	40.81
1975 – 76	53640	961328	223500	137196	335578	86304	38.61
1976 – 77	51565	1059860	214851	74131	180800	140720	65.50
1977 – 78	39111	1476121	162962	60194	187199	102768	63.06

marketing season go to several places in the producing areas for the collection. Only a small quantity of the nuts is disposed of by the farmers themselves.

As there are a number of intermediaries operating in the field between the primary producer and the processing units, the different costs and margins in the total spread between the producer and the processing unit are quite significant and the producer's share in the price paid by the processing unit is generally low. Besides this, the inefficient collection of raw nuts also results in lesser return to the producer.

Co-operative marketing in cashewnut has not developed to the desired extent as in the case of other commercial crops.

Marketing and pricing policy plays an important role in cashew industry. The grower requires a remunerative price and the processor-cum-exporter needs a reasonable and predictable price. The internal price of rawnuts depends on the international price of kernels. The rawnut price in the country should be above the parity price of the grower (Pg) which after covering the cost of production enables the grower to earn a reasonable margin of profit and below the partity price of the processor-cum-exporter (Pp) which after covering the normal processing and marketing costs enables the processor to sell the kernels at their current price. Therefore, the total cost of marketing from the grower to the processor should be less than Pp minus Pg.

The parity price of the processor for raw nuts in Kerala for different prices of cashew kernels of 320 counts in New York ranging from U. S. $1.50 to 2.50 per lb have been worked out and given in table 2. In this analysis, the average kernel price received by the exporter has been estimated at 8 per cent less than the New York price for 320 counts, as the kernel recovery of the grades below 320 counts is more than those above 320 counts,

The wages of agricultural as well as industrial labourer in Kerala are higher than in other states. Therefore, the parity price of rawnut for the grower and the processor-cum-exporter in Kerala are also applicable to the other states to the advantage of both the grower and the processor. If the market price falls below the parity price of the grower, it will not be an economic price for the cultivator and if the price is above the parity price of the processor, he will not be prepared to purchase the rawnuts as he will have to incur a loss. Therefore, the level of support should be determined by an equilibrium price taking into consideration the cost of cultivation and price of the processing unit.

Though, with proper management, scientific planting techniques and timely input application, there is potential to realise yields upto 1500 kg

TABLE 2. **The Parity Prices for the Processor for Rawnuts in Kerala for Different Prices of Cashew Kernels of 320 Counts in New York.**

Price for 320 counts in New York (in \$/lb)	*Representative average price* (in \$/lb)*	*Commission and freight charges (in cents)*	*Net price received by the exporter (in \$/lb)*	*Value for 52.92 lb of cashew kernels** (in Rs.)*	*Parity price of the processor for raw-nuts in Rs./kg*
1.50	1.38	9.45	1.29	546.13	3.31
1.60	1.47	9.68	1.37	579.78	3.65
1.70	1.56	9.90	1.46	617.87	4.03
1.80	1.66	10.15	1.56	660.19	4.45
1.90	1.75	10.38	1.65	698.28	4.83
2.00	1.84	10.60	1.73	732.14	5.17
2.10	1.93	10.83	1.82	770.22	5.55
2.20	2.02	11.05	1.91	808.31	5.93
2.30	2.12	11.30	2.01	850.63	6.36
2.40	2.21	11.52	2.09	884.49	6.69
2.50	2.30	11.75	2.18	922.58	7.08

*Average price for all the counts taken together received by the processor cum-exporter.

**Kernel recovery @ 24 per cent will yield 52.92 lbs. of cashew kernels per quintal of rawnuts processed at a processing cost of Rs. 215.00/quintal.

per hectare in the long run, it has been assumed for the purpose of economic analysis that the yield will go up from 100 kg per hectare in the fifth year to 1000 kg per hectare in the tenth year under new plantations. Economic analysis for one hectare model for 15 years has been attempted. The benefit to the grower has been worked out at Rs. 3.50 per kg of raw nuts. The opportunity cost of capital for cost benefit ratio has been assumed at 11 per cent and it turned out to be 1:1.20. The internal rate of return for this period has turned out to be 15.9 per cent. When the benefit was calculated at Rs. 4/- per kg, cost benefit ratio for this has turned out to be 1:1.35 and the international rate of return to be 19.2 per cent. As the break even period works out to be the eleventh year when the benefit is calculated at Rs. 3.50 per kg and tenth year at Rs. 4 per kg. However, the trend in the international kernel price will have great effect on the parity price of the processor. The prices of raw nuts in the country as well as the kernel prices in the international market were slowly moving upward till 1974. But in the following year the raw nut prices in India had slightly fallen while the international kernel prices were ruling more or less steady. During this period the cost of processing of raw nuts in the country has increased by 48 per cent. The prices of both the raw nuts and kernels reached the maximum level in 1977 and decline in the following year. The processing cost has further increased by 17 per cent in 1978. The downward trend in the price of kernels in international market had severely affected the export of Indian cashew in the year 1978. When there is a difference of 5 cents per 1 lb of 320 counts of kernels in the International markets, the analysis shows that there should be a corresponding difference of 20 paise per kg of raw nuts in the country and *vice versa*. When there is an increase in the fixed cost in the marketing system which cannot be eliminated without a corresponding increase in the kernel price, the only alternative is to reduce the unit cost of production. Price stabilization and price support have a great deal of effect on the efficiency of the marketing systems.

Discussions:

J.G. Ohler: We seem to agree on many points except in the conclusion. How can you fix an international consumer prize? If you fix this price too high because your production cost is too high, how do you expect to influence the individual consumer who resists to buy at your fixed price?

L. Krishnaswamy: It is not possible to fix an international consumer price for cashew since cashew has to be compete with other tree nuts vis-a-vis rate of inflationary trends that might affect this luxury meat. The question of fixing high price does not arise. It is only the question of increasing productivity and unit area production to reduce cost of production; which should enable us to sell our cashew kernels at competitive prices in the world market.

Patterns and Trends in India's Export Trade in Cashew

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Cashew, a native of Brazil, was brought to India by the early Portuguese settlers over 400 years ago. Over the years it has established in this country and is now grown widely throughout the west coast of India and many other parts of the country viz. Tamil Nadu, Andhra Pradesh, Goa, Orissa and West Bengal. It was not until the beginning of the current century that cashew kernels were commercially produced for domestic consumption and export.

Between 1900 and the outbreak of the first World War in 1914, very small quantities of cashew kernels, still unpeeled, were exported from India mainly to Marseilles and occasionally to London, packed in mangowood cases lined with newspaper. Shortly after the first World War, a few trial shipments were made to New York, but infestation was a serious problem. The General Foods Corporation of U.S.A. first introduced the idea of packing cashew kernels in an atmosphere of carbon dioxide, a method which was patented by them during the early 1920's. It was this development which laid the foundation for a growing export trade in cashew kernels from India.

In the year 1923, total exports from India amounted to only 45 tons. By 1930 exports increased to about 2,300 tons and by 1939, 13,500 tons. During these years India's exports of cashew kernels were almost exclusively to the U.S.A. with small quantities being exported to the United Kingdom.

The second World War produced a set-back in India's exports of cashew kernels, but after the end of the war the industry quickly re-established itself and with a steady flow of raw cashewnuts from the East African producing countries to supplement the indigenous production, exports started growing. The growth in subsequent years almost until 1975 was indeed phenomenal.

Right from the beginning, the fillip for the growth of the Indian Cashew Industry was provided largely by the Importers and Salters in the U.S.A. who developed a consumer taste for the nut and built up a flourishing business in the roasting and salting of various kinds of tree nuts. For many years it was the U.S. market which accounted for more than 80 per cent of India's exports of cashew kernels.

Exports of cashew kernels from India from 1947 to 1978 are given in table 1. From an average annual export of less than 20,000 tons during 1947–50, India's exports rose to an annual average of 28,000 tons during 1951–55, 37,000 tons during 1956–60, 49,500 tons during 1961–65, 55,600 tons during 1966–70, and 60,000 tons during 1971–75. Since then exports have been declining and the year 1978 witnessed the lowest exports since 1951 at 23,800 tons.

During the period 1947–50, India's two major markets for cashew kernels were U.S.A. (accounting for about 80%) and U.K. (accounting for about 12%). The only other market of any consequence at that time was Canada (accounting for about 4%), although small quantities were also exported during this period to Belgium, Sweeden, New Zealand, etc. For a few years more this pattern continued, unitl India started looking for other markets and it was during 1951–55 that Australia and Netherlands started showing interest in Indian cashew kernels. However, during the five year period 1951–55, more than 90 per cent of India's exports were still accounted for by U.S.A. and U.K.

The year 1956 witnessed the entry of U.S.S.R. as a buyer of India's cashew kernels. During the five year period 1956–60, U.S.S.R's purchases from India remained small and amounted to about 9 per cent. However, this diversification was achieved at the expense of exports to U.S.A. which dropped to about 70 per cent during this period. Australia and the Netherlands also marginally increased their off-take of cashew kernels from India during these years, while several new markets started opening up. The more important among them were G.D.R., F.R.G., Italy, Switzerland, Bahrein, Kuwait, U.A.E., Saudi Arabia, Hong Kong, Japan, Malaysia, Singapore, Norway, Iran and Lebanon. Exports to these new markets were however relatively small in the beginning.

It was at about this time that the Cashew Export Promotion Council was established with a view to promoting exports to traditional markets and exploring new markets and the ten years from 1961 witnessed a further diversification of India's export trade in cashew kernels. The U.S.S.R. steadily improved its off-take of cashew kernels from India with the result that the share of exports to U.S.A. started declining. During 1961–65 U.S.A. and U.S.S.R. accounted for nearly 60 and 16 per cent of India's export of cashew kernels, while during 1966–70 the percentages altered to about 45 and 30 respectively.

TABLE 1. **Export of Cashew Kernels from India**

Year	*Quantity (tons)*	*Value (Rs. million)*	*Average value (Rs./Kg)*
1947–50 (Average)	19,300	55.00	2.85
1951–55 ,,	28,300	110.00	3.93
1956–60 ,,	37,000	155.00	4.19
1961	41,200	187.06	4.54
1962	46,400	185.15	3.99
1963	53,400	217.62	4.08
1964	52,650	264.93	5.03
1965	53,800	287.65	5.35
1966	48,600	376.37	7.74
1967	52,250	431.72	8.26
1968	60,500	574.20	9.49
1969	62,700	585.48	9.34
1970	54,100	558.24	10.32
1971	60,000	610.76	10.18
1972	64,550	665.31	10.31
1973	57,050	753.08	13.20
1974	58,000	1046.82	18.05
1975	59,200	1055.34	17.83
1976	55,950	1109.10	19.82
1977 (Prov.)	39,250	1431.43	36.01
1978 (Prov.)	23,820	752.10	31.57

Export of cashew kernels to major overseas markets during the period 1971–78 is given in Table 2. While some of the new outlets for Indian cashew

TABLE 2. **Statement of Indian Export of Cashew Kernels (Quantity in M. Tons)**

	1971	1972	1973	1974	1975	1976	1977*	1978*
U.S.A.	29,309	19,568	20,313	12,311	18,458	20,550	8,791	6,015
U.S.S.R.	16,485	25,385	20,700	31,742	24,797	15,755	19,597	8,885
Canada	3,788	5,486	3,978	3,615	2,830	3,974	1,286	604
Bulgaria	81	142	1	..	93	11	..	..
Czechoslovakia	675	952	744	533	90	41	158	189
G.D.R.	1,782	2,062	978	614	266	511	146	..
Hungary	61	95	46	30	..	..	..	..
Poland	108	135	..	27	..	..	..	..
Rumania	76	205	156	81	207	11	..	..
Belgium	116	221	124	188	160	136	121	13
France	198	401	156	160	471	311	189	239
G.F.R.	428	892	1,103	811	577	1,304	496	341
Italy	52	86	124	65	25	30	6	..
Netherlands	818	1,079	1,070	1,145	1,402	1,792	1,107	1,125
Spain	13	40	10	5	..	26	8	24

(contd.)

	1971	1972	1973	1974	1975	1976	1977*	1978*
Sweden	11	18	18	13	..	15	12	2
Switzerland	18	98	97	109	101	124	81	18
U.K.	1,638	1,991	1,503	910	808	1,015	383	490
Yougaslavia	235	164	78	20	20	..	10	43
Bahrein	70	102	84	74	192	193	164	127
Iran	150	121	85	96	179	225	181	28
Kuwait	94	131	181	260	421	535	413	609
Lebanon	107	223	202	152	166	5	35	43
U.A.E.	3	1	4	26	59	84	136	96
Hong Kong	832	1,017	548	832	858	532	578	293
Japan	1,194	2,001	3,168	1,509	3,769	5,480	3,001	3,441
Singapore	376	389	390	342	529	460	247	286
Malaysia	34	30	11	18	18	21	13	15
Australia	1,079	1,332	1,120	1,900	2,220	2,377	1,976	594
New Zealand	75	29	31	275	250	190	41	79
Total, including other destinations	59,985	64,542	57,062	57,976	59,174	55,940	39,255	23,820

* provisional

kernels showed an encouraging pattern of increased off-take during this period, it was still U. S. S. R. and U. S. A. who between them accounted for over 70 per cent of India's exports of cashew kernels. In certain years purchases by U.S.S.R. showed marked increase when exports to U.S.A. were proportionately lower. This is significant not from the point of view of the fluctuations in the share of India's exports to various markets, but for the fact that it shows the wide variety of markets opened up for Indian cashew kernels. Several other markets also contributed to India's exports, although the quantities involved were mostly small.

In considering the patterns and trends in India's exports of cashew kernels in the future, it must be pointed out that the Indian Cashew Industry grew to enormous heights in the last few decades, largely due to a steady supply of raw cashewnuts received from the East African producing countries. In recent years most of these countries have set up their own processing units with a view to consuming their production for raw nuts locally, thereby leaving less and less quantities for the Indian industry. The Indian industry can no longer depend on massive imports of raw cashewnuts from other countries and, unless indigenous production is stepped up adequately, and raw nuts made available to the processing industry at workable prices, the prospects for India being able to maintain its export quantum achieved during the first five years of the current decade will be extremely bleak. While it is encouraging that various State Governments in the country are making efforts to increase indigenous production of cashew, it looks as if during the coming few years India's export of cashew kernels will not be much more than 35,000 – 40,000 tons per annum.

With the emergence of several other major suppliers of cashew kernels to world markets like Mozambique, Tanzania, Kenya, Brazil and China, it must also be hoped that a wider cross section of new markets would be opened up in the coming years so that the world demand would grow and keep peace with the increased world production.

The Future of the Cashew Industry

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Abstract

Three factors on which cashew industry is dependent, i.e. the availability of raw material, the cost of production and stable market are highlighted in this paper. The important aspects which will help cashew industry in general are: increasing the yield through rehabilitation of old plantings and control of pests. The cost of production can be reduced by mechanical innovation and aids and by reducing the number of market grades. Attempts should be made to minimise the fluctuations in availability of raw material and finished products for stabilising cashew industry. Research financing and co-ordination are also discussed.

The future of the cashew industry depends on three main factors namely (i) The ready availability of clean, dry, high quality raw cashew nuts in sufficient quantities, (ii) the cost of processing, (iii) a stable market for high grade edible kernels. Since the weather has a profound influence on the cashew crop adverse conditions are a normal hazard. There are, however, other occurrences which affect the market and the industry.

These occurrences, in some instances, have no special relation to the Cashew Industry but the Industry prospered or suffered because of them. Devaluation, dock strikes, changes in government and financial legislation are just a few items that can have far reaching effects. On the other hand because of the prosperity or otherwise of the Industry, Governments have thought fit to Nationalise, Labour Organizations have thought fit to intervene, Marketing Organisations have been set up, buying Organisations have been brought into being, all of which have brought into conflict expertise and the lack of expertise however well meaning the latter might be.

This paper is not to question the desirability of Governmental interest in the Industry but to harness the Industry itself along with the research workers to apply themselves to the three factors defined at the opening of this paper and thus in some measure minimise the fluctuations of crop availability and make for a steadier market for the benefit of grower, worker, processor, trader, distributor and consumer, minimising the necessity for government intervention.

It is known that research on vegetative propagation has given some encouraging results and the application of these results to all the growing areas in Africa, South America as well as Asia could have far reaching effect on the availability of raw nuts for industry.

There have been some efforts to increase the availability of crop. India has had such programmes in the succeeding Five Year Plans since 1950. The export availability of the crop has increased very little since 1950 as compared with Tanzania over the same period. The choice between the expansion of the area and rehabilitation of existing plantations has to be critically evaluated.

The southern regions of Tanzania had a programme for strengthening the extension service on cashew production. It would be of interest to learn the success of the programme. The Cashew Authority of Tanzania were to be the implementing agency of such a World Bank financed programme and other countries could learn from their experience.

Notwithstanding the propagation of high grade planting material, there is considerable loss of crop due to insect attack. By far the greatest loss of crop is attributed to the attack by *Helopeltis* spp. Estimates by the writer of crop loss have varied between 10 to 75 per cent between season and/or localities. Thus if control or complete elimination of *Helopeltis* could be achieved then crop yields would dramatically increase and will have the desired effect of increasing crop availability without increasing the area under cashew cultivation and along with rehabilitation suggested earlier would provide the desired answer without encroaching on land which could be used for food crops or other more sophisticated crops.

Helopeltis spp. occur in Africa and the maps produced by the Commonwealth Institute of Entomology show that *Helopeltis schoutendeni* (Reut.) occurs throughout the growing areas of East Africa but for some reason not in Madagascar. It also occurs in most areas in West Africa but shows Senegal as free of the species and this fact was noted by the writer on a visit in 1977 that cashew trees in the Sine Saloum area of Senegal showed no signs of *Helopeltis* attack. However in Nigeria, Benin, Ghana and Ivory Coast *Helopeltis* attack is common.

The maps also show that in Asia, the West Coast of India from Goa south to Comorin and all the East Coast extending into Bangladesh including the Chittagong area, *Helopeltis antonii* (Sign.) occurs. Also Malaysia, Indonesia and the Indo-China area shows occurrence. For some reason the map leaves out Sri Lanka and the writer knows from his own observations that the cashew plantations there suffer badly from *Helopeltis* attack. There is no record of *Helopeltis* being a problem in Brazil or elsewhere in the New World.

It has been reported that chemical spraying has produced some measure of control. It is also reported that chemical spraying of larger areas from aircraft has shown encouraging results in India. Whatever the results of chemical spraying may be, the pest will survive and the spraying may have to be repeated during any one season and in any case repeated every year.

Anacardium occidentale is indigenous to Brazil and is, therefore, an imported species to both Africa and Asia. *Helopeltis* spp. however is a native insect of both Africa and Asia and although the original host is possibly not known it is known that the species is found on a wide variety of plants including *Anacardium occidentale.*

While chemical control may be the interim answer, the biological control may provide the solution in the long run and it should be investigated.

There are other insects which attack the cashew tree and some of these are more prevalent in some areas than in others. A few are as follows:

(a) *Analoptis trifasciata:* this insect rings a tree branch which eventually breaks off. The eggs are laid in the fallen branch; prevalent in Nigeria.

(b) *Zonocerus variegatus:* attacks the bark and leaf; Nigeria.

(c) *Selenothrips rubrocinctus:* produces defoliation; Tanzania.

(d) *Pseudotheraptus wayii:* which is responsible for the black spot on mature kernels. Very important in East Africa, particularly in Tanzania.

(e) *Aleurodocis cocois* (white fly): on cashew in Brazil. The Commonwealth Institute of Biological Control with its headquarters in West Indies may take up investigations on the control in collaboration with the national, research agencies on these pests.

Finance for research as in the case of other agricultural products and allied agro-industry should be the responsibility of the industry. In the past the crop was much smaller and the market price of the kernel was much lower but even then India placed a cess on the exported kernel to finance research. If this is still the case it should be continued, if not it should be reintroduced and such an arrangement be introduced in all other exporting countries and thus industry would be paying for research on all aspects of the raw material for the benefit of both grower and processor.

Assuming such arrangements were to materialise then industry should have some say in the research programme to be undertaken and at the same time be prepared to feed back to research, experiences as a result of implementing research findings.

The problems are international and international co-ordination of research is not only essential but also is the only way that information can be disseminated internationally. It is proposed that an International Committee be set up for:

1. Raising finances for research on all cashew problems to be placed in a Research Fund and distributed as required to Research Establishments
2. Co-ordinating Research on all cashew problems
3. Disseminating information on all research carried out
4. Receiving from participating countries proposals for research
5. Co-ordinating exchange of planting material between countries
6. Enlisting assistance on research problems from Institutions where specialised knowledge in the field is available
7. Reporting to participating countries annually on work done by the Committee during the year
8. Finance for the International Committee and its Secretarial Services to come from the Research Fund

The cost of the nuts in the market is greatly influenced by the processing methods. One of the alternatives is to mechanise the processing atleast to some extent. This should also be followed by diversification of labour to other areas.

Currently there are number of grades of cashew and the cost of producing a large number of grades is greater than a few readily saleable grades. Grading cost could be considerably reduced if the following grades only were made.

Export Grades: Natural Wholes, Scorched Wholes, Dessert Wholes
Butts, Splits
Pieces, Scorched Pieces
Small Pieces, Small Scorched Pieces
Baby Bits.

Scorched Butts and Splits go into Scorched pieces. Other Dessert grades may be sold locally.

The price that can be paid for the raw nut varied with the price at which the kernel may be sold. Resistance from kernel buyers will force the processor to lower his price for the raw nut, other things being equal.

Some Governments or purchasing authorities fix the price at which raw nuts will be purchased. This price is highly sensitive to political manipulation and as in the case of Kerala in some seasons it is financially disastrous.

Price equalisation suggests a possible solution, whereby buying authorities will guarantee a price to the grower over a period of years and act as a buffer between the grower and processor. The buying authority will sell to the processor at the going market rate and take the profit into an equalisation fund. This allows the buying authority to continue to pay the same price to the grower irrespective of the variations of the raw nut or the kernel markets. The price to the grower may be varied upwards as and when the equalisation fund permits and the fund must be protected from misuse and should earn interest without risk at all times. The prices to the grower should be so fixed that the fund will always be at credit and will be held in trust for the growers.

The emphasis on the research aspect of cashew production would be purely academic if vastly increased production was not realised and the industry must gear itself to process and sell high grade edible kernels in vastly increased quantities.

Cashew, has it a Future?

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Abstract

The history of cashew production, consumption, prices and the present cashew situation are reviewed. The relationship between consumer price, processing cost and farm gate price is discussed, along with the possibilities of increased efficiency in production and processing methods. It is concluded that the answer to the question of cashew's future can be positive if the research on cashew production and processing is intensified.

The prospects of a commodity depends on the basic economic law of supply, demand and price. Although cashew was grown in large areas in the early twenties when cashew kernels entered the world market, it was only after World War II that the production mark of 100,000 tons of raw cashew nuts (RCN) was reached. But production increased steadily as a result of more intensive collection of the nuts from spontaneously and sub-spontaneously growing cashew trees as well as a result of new plantings by small holders. If the various countries carry out their envisaged planting programmes, it is expected that world production of cashew will reach 500,000 tons in 1980, 750,000 tons in 1985 and 900,000 tons in 1990.

In 1955 total production was about 125,000 tons of RCN, in 1960 it had increased to 160,000 tons and in 1975 to 470,000 tons. Since then, production in Mozambique and Tanzania, the two major producing countries has decreased considerably due to infrastructural problems. It may be assumed that this will only be a temporary situation, but the stagnation in supply caused a very steep price increase.

Demand has kept pace with production, or *vice versa*. The first consignments were exported from India to the U.S.A. Cashew is consumed in many countries now is an indication that the market has widened considerably. The per capita consumption differs greatly in different countries as is shown in table 1.

Even in the top four countries the consumption of Canada is almost 75 per cent higher than that of the Netherlands which is the highest consumer in Europe. The consumption in the Netherlands is about four times as high as that of its close neighbours, W. Germany and Belgium that have about the same level of income. Such differences indicate that there is still a great potential market in the developed countries that has not yet been fully exploited. If we assume that the total population of the developed countries at one billion and that two thirds of this population would increase their consumption by only 100 g per capita, then total consumption would increase by 66,000 tons of kernels, corresponding with about 300,000 tons of RCN. Besides the developed countries there still is an enormous market potential in the developing countries. As far as the potential market concerns, the answer to the question about cashew's future can be positive.

TABLE 1. **Per Capita Consumption of Cashew Kernels (g) in various Countries (1972)**

Canada	265	U.K.	54
U.S.A.	226	West Germany	40
Australia	199	Belgium	33
Netherlands	154	France	20
East Germany	102	Japan	17
U.S.S.R.	62		

Source: Navilla, 1973.

However, demand depends not only on the attractiveness of the product but also on its price. It is difficult to compare prices over a long period of time because of the changes in the value of the money and in the earning capacities of the people in the various countries. Therefore no detailed price analysis will be presented, the price development will be looked at as a trend only.

Between the end of the world war to about 1964 the prices of cashew kernels varied between US \$ 0.55 – 0.65 per lb. Between 1964 and 1973 they varied between US \$ 0.65 – 0.80 per lb. But at the end of 1973 and the beginning of 1974 the price leaped suddenly to US \$ 1.20 – 1.30 per lb. As cashew is a luxury product one would expect the demand to fall during the time of the oil crisis that increased prices for many articles of daily need. But cashew kernel prices remained firm and increased to a peak of about US \$ 2.40 at the end of 1977 and early 1978. The main cause for this rise in price was the shortage of supply, mainly caused by the considerably lower productions in Mozambique and Tanzania.

Apparently the prices went through the ceiling, resulting in consumers resistance. As a result prices tumbled to a level of US $ 1.72 per lb, a drop of about 28 per cent. It is possible that prices will fall even more. In the mean time world production may recuperate its former level and in the coming years increased RCN production may be expected. As a result, prices might be expected to remain at the actual level or to drop even more.

To answer the question of future of cashew the following equation can be used.

$$R = SK - (P + M)$$

R = Raw nut price in US $/kg (factory - gate price)
S = shelling percentage
K = Kernel price in US $/lb.
M = Margin of profit of processing enterprise
P = Processing cost in US $/lb.
Under Kerala conditions this would give the following result (US $ 1 = ca. Rs. 8/- in 1979)
R = Rs. 3.70 per kg of RCN
S = 250 g = 0.53 lb per kg RCN
K = World market price = US $ 1.72/lb.
Rs. 3.70 = US $ 0.53 x 1.72 — (P + M)
Rs. 3.70 = US $ 0.91 — (P + M)
US $ 0.45 = US $ 0.91 — (P + M)
P + M = US $ 0.91 — 0.45 = US $ 0.56

This means that unless the industry can process raw cashew nuts at a price of less than US $ 0.56 = Rs. 4.5 per lb no profit can be made. The estimated processing cost, given by the Directorate of Cashewnut Development in India, is Rs. 175/- per bag of 20 kg of RCN, or US $ 21.55 per 42.6 lb of kernels = US $ 0.50 per lb of kernel. If this figure is right, this would mean that at present price level the industry is losing money. Even if the estimated cost is too high, it is clear that the industry is meeting serious problems at the moment with cashew industry labour demanding 20 per cent higher wages and cashew farmers grumbling over low prices for their nuts. The answer to the question, about cashew's future at this stage cannot be very optimistic.

Solution to this problem depends on the shelling percentage, which in India is about 24 per cent with the presently available plant material and improvement may not be possible. Average kernel content is about 28.30 per cent and a certain part inevitably is lost during processing. Selected plant material may contain 30.36 per cent kernel, which still is not a great improvement, but it could mean the difference between a loss and a profit for the industry. But it will take many years before all available cashewnuts would be of this quality. Thus, no immediate solution may be expected through plant material improvement. In this context, I would like to draw the attention to the existance of nuts with very thin shells that do not contain CNSL. Such nuts might have a kernel percentage of about 60. Moreover, processing costs of such nuts might be considerably lower. The trees that produce such nuts are known to be low yielders, but the characteristic could be bred into high yielding varieties. It would take a long time before such nuts would become available in large quantities but it is certainly not a factor to be overlooked.

The world market kernel price that can hardly be influenced by the producers. The consumer will determine how much money to be spent on cashew nuts or any other nut.

Processing cost can hardly be expected to reduce. Wages and material costs have an upward trend and no reduction will be possible. However, immediate possibility for cost reduction is possible in packing. For about 50 years cashew has been packed in vacuumised tins. These tins are expensive, especially for small factories in remote areas that often have to transport voluminous empty tins to the factory because it would be even less economic to produce tins at the processing site. Presently such tins are largely replaced by containers of aluminised paper, that can be produced in exactly the same shape as the original tins. In Europe even liquid products are packed in such containers. Such containers can be vacuumized as easily as tins. They can be made at the factory site without any special skill. Material can be delivered in sheets. The material is less costly than metal. There may be a resistance from the dealers against a new way of packing. But if dealers or brokers do not contribute their share to make cashew processing less expensive, then very soon they will not have any more cashew to deal with.

The factory gate price of RCN, is the last factor. Cashew is a very neglected crop grown on marginal lands and yields are very low. In Kerala an average yield of about 1,000 kg/ha is claimed. But results of hundreds of demonstration plots have shown that initial yields are nearer to 300 - 400 kg/ha. But the same demonstration plots have shown that with spraying against *Helopeltis* and by fertilizing, yields of most of the plots reached the 1,000 kg level, or approximately 3 times as much as before. At this yield level, after deduction of extra treatment cost, the income of the farmer is much higher and he can produce at a much lower price and still have a higher net income. This is the only available short-term solution to the present problems, intensive farming instead of extensive farming. Extension of area under cashew without better production techniques will only increase the magnitude of the problem.

There is yet another factor namely better use of by-products especially apple is of very great importance and this can help the farmer to produce RCN at economic prices. It is a shame that in times of today when many people suffer from hunger, a good food as the apple is thrown away. Brazil has set the example of profitable use of the apple. In Brazil a great variety of cashew apple products can be found in all food shops throughout the country, also in those parts where cashew does not grow. Some estates in Brazil are considering the value of the apple to be great as that of the nut. Such a development would be an enormous support for the financial position of the farmer and allow him to produce RCN at a much lower price. Therefore, moraly and economically it is of the greatest importance that apple. harvesting and processing becomes a normal part of the cashew industry There are doubts about the acceptability of the apple products because of their peculiar taste and aroma, but the Brazilian case has shown that such difficulties can be overcome.

We may conclude that the final answer to the question to the cashew's future can be positive only on condition that great efforts will be made to intensify production methods at farmer's level and that full use be made of the by-products. Other improvements in cashew production exist, but will take too much time before appreciable results may be expected.

Discussion

M.R. Mulele: Will you please tell us about large estate plantations and small holder schemes vis-a-vis increasing and intensifying cashew cultivation.

J.G. Ohler: A small holder, who does not pay labour costs, is more flexible than an estate. But when it comes to intensifying the cultivation for which investment is needed, the estate has the advantages of having financial resources. So, if we do not take care of our smallholders' cashew may develop into an estate crop instead of a smallholders crop.

BOTANY, PHYSIOLOGY AND CROP IMPROVEMENT

Genetic Improvement of Cashew in Kerala

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In order to improve the genetic stock, selection and breeding were undertaken at the Cashew Research Station, Anakkayam and Mannuthy. The programme involved (i) Identification of superior genotypes in the existing population (ii) Evolution of better varieties by hybridization and selection in the F_1 and (iii) Multiplication of the selected types by an effective method of vegetative propagation. Development of mono-clonal and poly-clonal seed orchards of the selected types is also in progress to overcome the limitations of vegetative propagation methods. Based on the economic characters, 16 types including a few hybrids which have given a mean yield of over 10 kg of nuts from the sixth to tenth year of orchard life have been selected. Four of these are now under pre-release multiplication.

Evaluation of the F_1 populations of the four crosses made in 1963 indicated that more number of productive hybrids were derived from the crosses in which one of the parents was exotic as compared to the progenies of crosses in which both the parents were indigenous.

Variation in Open Pollinated Seedling Progenies in Cashew

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A study was conducted in the College of Horticulture, Kerala Agricultural University, Trichur during the year 1977–78 to find out the extent of variation in vegetative, flowering, apple, and yield characters of 100 seedling progenies derived from open pollinated single mother tree (T – 20). The objective of the study was to assess the suitability or otherwise of selecting seeds from a single high yielding type for propagation. Considerable variation was observed in vigour of trees expressed as height, spread and number of primary branches in both the years. Girth was the least variable attribute.

Flowering also varied considerably between the individuals. Qualitative characters of apples similarly varied to a considerable extent. Yield of nuts during both the years was also highly variable. The fact that inspite of single tree selection, more than 50 per cent of trees yielded below the mean suggest that greater caution has to be exercised while realising seeds of selected types as high yielders. Vegetative propagation is perhaps the only assurance for the transmission of characters from mother tree to their progenies.

Epidermal Morphology and Stomatal Development in Anacardiaceae

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Dermal morphology and stomatal ontogeny of *Spondias pinnata* (L.f.) Kurz., *Lannea coromandelica* (Houtt.) Merr., *Anacardium occidentale* L., *Holigarna arnottiana* Hook. f. and *Mangifera indica* L. are studied. The cuticle is thick in *H. arnottiana, A. occidentale* and *M. indica,* but is thin in *S. pinnata* and *L. coromandelica.* Based on the shape of epidermal cells, the five species are categorised into three: cells in both upper and lower epidermis sinuous (*A. occidentale, H. arnottiana, S. pinnata*); upper sinuous and lower polygonal (*M. indica*) and upper polygonal and lower sinuous (*L. coromandelica*). Stomatal ontogeny aperigenous (*L. coromandelica*), paramesoperigenous (*A. occidentale*) and anisomesogenous (*M. indica, H. arnottiana*). *S. pinnata* is peculiar in that it possesses three different types of stomata, aperigenous, hemiparamesoperigenous and paramesoperigenous; whereas, in all the other four species only one type of stomatal ontogenesis exists. Except *S. pinnata* all the other species possess epidermal appendages. Unicellular trichomes occur in *A. occidentale* and *H. arnottiana,* and multicellular glandular trichomes in *A. occidentale, M. indica* and *L. coromandelica.* The multicellular hairs are found in *A. occidentale* in specialized pockets in two rows on either side of the major veins — a unique feature which is reported here for the first time.

Specific Gravity of Seeds as a Mass Selection Criterian in Cashew

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Cashew seeds drawn from a bulk collection were grouped into different specific gravity groups by immersing them in a series of sugar solutions of increasing specific gravity, and samples from each group were raised in polythene bags. Seeds of higher specific gravity gave significantly earlier and higher rates of germination: 50 and 97 per cent in the lowest (1.03) and highest (1.09) specific gravity groups respectively. A vigour index calculated based on speed and rate of germination gave index values 4.16, 7.08, 7.33 and 8.17 for the groups 1.03, 1.03 – 1.06, 1.06 – 1.09 and 1.09 respectively. The greater the index value, the greater the germination ability and thus the greater the seed vigour.

The low specific gravity seeds were significantly inferior to high specific gravity seeds in shoot length, shoot girth, fresh and dry weight of shoots. In general seed specific gravity affected seed germination and seedling growth significantly. These results indicate the possibility of mass selection of seeds for greater vigour. Since 45 per cent of the seeds fall in the low specific gravity groups elimination of these can enhance the speed of germination, ensure vigorous seedlings and also reduce the loss by way of ungerminated seeds and seedlings of low vigour.

Flowering Behaviour and Correlation Studies in Cashew

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The flowering behaviour and nut set of cashew (*Anacardium occidentale* L.) were investigated. Ten units of 30 cm^2 area per tree at different heights and sides of a tree in fifteen healthy bearing trees of almost same age group were studied. Observations per unit area on number of male flowers (1766.04), number of bisexual flowers (61.99), number of nuts set (1.40), percentage of bisexual flowers to male flowers (4.12), percentage of nuts set

to bisexual flowers (4.57) and number of panicles (flowering shoots) (4.55) were made. Correlation coefficients were worked out between the observed characters.

(i) Between number of panicles and number of flowers (0.0085)

(ii) Between number of panicles and number of bisexual flowers (0.2028)

(iii) Between number of panicles and number of nuts set (0.1661)

(iv) Between number of male flowers and bisexual flowers (0.0810)

(v) Between number of male flowers and number of nuts set (0.0119)

(vi) Between number of bisexual flowers and number of nuts set (0.2301)

The correlation coefficients (i) between number of panicles and bisexual flowers, and (ii) between number of bisexual flowers and number of nuts set were statistically significant.

Study of Microsporogenesis in Cashew

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Six cashew trees growing at the C.P.C.R.I. Kasaragod campus were selected for this study. For meiotic studies, the flower buds were fixed in freshly prepared Carnoy's solution (6:3:1 alcohol: chloroform: acetic acid) between 2 and 3 p.m. and refrigerated for 24 hrs and then transferred to 70 per cent alcohol after treating the buds with ferric acetate. Squash preparations of anthers, with acetocarmine were made for the study of microsporogenesis. Pollen stainability was determined by using 1:1 acetocarmine: glycerine.

The meiotic behaviour was found to be uniform in all the six trees examined. At metaphase I, 63 to 68 per cent of the cells showed 21 bivalents.

The mean chiasmata per cell and the between cell variance (within plant variation) have been analysed. In cashew, the frequency of chiasmata ranged from 39 to 42 per cell and the cell variance within a tree ranged from 0.25 to 1.1. Most of the cells showed 19 ring bivalents and 2 rod bivalents, and two of the bivalents consistently showed unterminalised chiasmata at metaphase I.

Out of the 223 cells observed at metaphase I, 144 were found to be normal possessing 21 bivalents. The rest showed irregularities like chromosome mosaics, suggesting premeiotic irregularities and stickiness of chromosomes. Among the chromosome mosaic cells, 26 – 28 per cent showed 20 bivalents. Two cells, one each from tree No. 1 and 3 showed 10 bivalents. Sticky association involving all the bivalents were noticed in 1–8 per cent of the cells. These cells behave abnormally in the subsequent stages of meiosis resulting in the formation of irregularities like laggards at anaphase and telophase. Thus up to 11 per cent of the cells at anaphase and up to 10 per cent of the cells at telophase exhibited lagging chromosomes. At sporad stage 2 – 5 per cent cells showed monads and 0 – 1 per cent pentads. Pollen stainability in acetocarmine varied from 78 to 86 per cent. The high percentage of sterile pollen grains (14 to 22 %) indicate that all the meiotic irregularities ultimately result in the formation of sterile pollen grains.

Vegetative Propagation in Cashew

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Budding and grafting operations were conducted from December (1977) to September (1978) taking five varieties (Tree No. 1, Hyb 2/12, Ansur No. 1, M 6/1, H 4 – 7) as scion material over local root stock of less than one year of age, under nursery condition.

Compared to 'T' budding, side grafting was more successful. January, February, September, July and June were found to be most suitable period for side grafting with decreasing order of success (80 to 60%), where as less than 16 per cent success was recorded in case of 'T' budding.

So far as varieties are concerned 60 to 100 per cent success in side grafting was obtained in all the varieties when grafting was done in above mentioned period.

Increase Cashew Production Adopting Vegetative Propagation

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To find out the suitable age of seedlings, the best time for patch budding/ veneer grafting and their comparative success, five monthly sowings from May to September; budding/grafting from November to March and two methods of propagation viz. patch budding and veneer grafting were studied. In case of veneer grafting, both defoliated and undefoliated scions were tried. In addition, the comparative performance of patch budding and veneer grafting was studied *in situ* also, on one year old seedlings during rainy season. Percentage success in both the cases (potted and *in situ* seedlings) was recorded after sprouting i.e. about two and half months after the operation.

The results obtained from propagation trials indicate that patch budding gave better success (61%) than veneer grafting (36%) in potted seedlings and the performance of 6 to 7 months old seedlings was found satisfactory. In the case of veneer grafting, undefoliated scions were found to be a complete failure and hence defoliation, about a week prior to grafting operation was found essential.

However, the observations recorded *in situ* reveal that veneer grafting gave as high as 92 per cent success as against 62 per cent in case of patch budding during rainy season.

For large scale multiplication of promising clones, seeds should be sown in alkathene bags during September - October and patch budding operation should be undertaken during March (i.e on about 6 months old seedlings), so that the sprouted buddings could be planted just before the onset of monsoon. For quick multiplication, budding is preferable over grafting since more number of buds can be had than scions per unit area of clonal material.

Preliminary Studies on Propagation of Cashew by Stooling and Layering

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Experiments have been carried out to propagate cashew vegetatively adopting, budding, grafting and air-layering with varied degrees of success. But, no detailed study seemed to have been made to propagate cashew by stooling and layering. Hence, trials were taken up on mound layering in cashew at C.P.C.R.I. Regional Station, Vittal, in 1978.

Fifteen adult trees of cashew were subjected to stooling during the second fortnight of February 1978. The girth of each stool was measured to find out correlation, if any, between stool girth and the number of coppice produced. The coppice produced were covered with a mound of sand at the basal portion during the first week of May 1978. After etiolation for about 40 days, the basal portion of the stools were cintcured and treated with IBA for quick rooting and again covered with sand for rooting to take place. The shoots were observed for rooting during first week of August 1978, and the rooted ones were separated and planted in polybags for further studies.

The process was repeated with another set of fifty shoots. The etiolated shoots were cinctured during last week of September 1978 and observed for rooting during the last week of October 1978 and the rooted layers were planted in containers.

The studies revealed that the coppiced trees with larger girth (36 – 40 cm) produced more number of shoots showing a declining trend as the girth size decreased (16 – 20 cm). The percentage availability of cinctured shoots gradually declined with the increase in girth size and this was due to over-crowding of more number of slender shoots emerged from the coppiced tree.

Different girths of coppiced trees were classified under five groups viz. 16–20, 21–25, 26–30, 31 – 35 and 36 – 40 cm and the number of shoots produced in each group were noted. It was found that the trees of higher girth ranges produced more number of shoots than those with lesser girth of coppiced trees.

Out of 157 shoots treated for rooting, 64.3 per cent had struck roots from the first batch and out of fifty shoots cinctured in the last week of September 1978, 44 per cent of them had struck roots.

One hundred shoots were cinctured for the third time in the last week of November 1978 of which 55 per cent success in rooting was observed.

There is a scope for quick multiplication of promising types in cashew in larger numbers economically, adopting stooling and layering as a technique.

Studies on Cashewnut Air-Layers I. Use of Different Decomposable Containers and Potting Mixtures as Aids in Maximising Field Survival and Establishment

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Two decomposable containers viz. straw pot and coconut husk pot and four potting media were tried to study their effect on the survival and establishment of cashew air layers in the field.

Planting the layers along with the decomposable containers in which they were raised viz., coconut husk pot and straw pot gave 86 and 62.3 per cent field survival respectively as against the survival rate of 32.6 per cent from the usual method of transplanting from clay pot. The different potting mixtures had no effect on improving the field survival of cashew air-layers.

The use of coconut husk pot apart from securing the highest field survival also proved to be a favourable medium for the better initial growth of young plants in the field. In the final analysis the use of coconut husk pot was found to be cheaper as well as practicable for the cultivator to establish cashew plantations, with air-layers.

Studies on Cashewnut Air-Layers II. The Morphological and Anatomical Characters of Roots in Relation to Transplantation Shock and Subsequent Field Mortality

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Air layering was known to be a successful method of vegetative propagation for cashewnut. But its large scale adoption by the cultivator is limited on account of the very high rate of mortality ranging from 50 to 70 per cent under field conditions on transplantation. Studies on morphological, physical and anatomical characters of the roots of cashew, guava and lemon air -layers were taken up in this study with the objective of identifying the factors which contribute to their mortality or survival in the field. Inadequacy of the root system of cashewnut in contrast to guava and lemon is mainfested in the low number and growth of intial roots, low specific gravity and high moisture content, poor development of mechanical tissues and low resistance to applied pressure. These factors make the roots of cashewnut air-layers extremely succulent, brittle and suceptible to easy damage at the slightest disturbance at the time of transplantation.

A Comparative Study of Different Methods of Vegetative Propagation of Cashew

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Studies on the different methods of vegetative propagation of cashew, viz. air-layering, side grafting, veneer grafting, wedge grafting and patch budding were carried out during the period 1974 to 1978 at the Cashew Research Station, Vellanikkara.

The best time for air-layering was from February to April during which period the shoot growth was also active. Treatment with IBA 250 ppm and NAA 500 ppm gave the maximum number of rooted layers. The percentage of rooting was positively correlated with shoot growth. Rooting was also found to be positively correlated with the maximum atmospheric temperature. Establishment of air-layers was better in ploythene bags with a mixture of soil, sand and compost as medium and which was supplied with Hewitts nutrient solution.

The highest percentage of establishment was obtained in side grafting, veneer grafting and budding during the monsoon period; starting from May-June and ending with September-October. After October, the percentage of establishment was practically nil in the case of both side grafting and veneer grafting. But in the case of budding there was some establishment even during summer months, unlike in the case of the other methods.

Wedge grafting under mist on eight month old seedings, gave a better success of 75 per cent in March compared to that of 70 per cent in February.

AGRONOMY
AND PLANT NUTRITION

Effect of Season Position and Age of Leaf on the Major Nutrient Composition of Cashew

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The major nutrients are found to deplete in older leaves and accumulate in the fully matured leaves of the current season's growth. The magnitude of variance in the nutrient contents of the bottom and top fully matured leaves is found marginal.

The nutrient variability as influenced by the season, position of the leaf and age of the leaf was studied in eight year old cashew trees. Twenty trees were selected for sampling purpose. Fresh and fully matured leaves were collected all around the tree at two positions i.e., bottom and top, before and after flowering i.e., January and May and analysed for major nutrients.

Effect of season

N.P and K. contents of fully matured leaves were significantly higher during May compared to January (Table 1).

Effect of position

N.P and K. contents of cashew leaves collected either from bottom or top positions did not differ significantly during both seasons (Table 1).

Effect of age

Before fruiting, N contents of fully matured leaves of previous flush maintained higher values as compared to the new flush. However, after fruiting freshly matured leaves recorded significantly higher content of nitrogen compared to matured leaves of pre-fruiting season. (Table 1).

Phosphorus and potassium

A marginal increase in phosphorus and potassium contents of new flush was observed before fruiting as compared to the matured leaves of previous season. However, after fruiting the increase in phosphorus and potassium contents of fully matured leaves of that season was three fold and significantly superior to matured leaves of pre-fruiting season.

TABLE 1. **Effect of Season, Leaf Position and Age on the Nutrient Composition of Cashew Leaf**

		% of		
		N	*P*	*K*
Effect of season				
Before fruiting	(January)	1.41	0.09	0.63
After fruiting	(May)	1.49	0.12	0.79
Effect of leaf position				
Before fruiting	Bottom	1.37	0.09	0.68
	Top	1.46	0.09	0.58
After fruiting	Bottom	1.49	1.12	0.81
	Top	1.49	1.12	0.77
Effect of Age				
Before fruiting				
Fully matured (previous season)		1.49	0.08	0.60
Freshly matured (current season)		1.34	0.09	0.66
After fruiting				
Fully matured (previous season)		1.19	0.06	0.46
Freshly matured (current season)		1.79	0.18	1.13

An Easy Technique for Predicting the Seedling Vigour in Cashew

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To evolve criteria for selection of quality seedlings in cashew a preliminary study was taken up. The dry weight of the seedlings is taken as a measure of its vigour. To evolve a non-destructive and easy method of estimating the total dry weight, correlations were worked out between the total dry weight, total leaf area and total leaf weight besides the individual leaf area and individual leaf weight.

Total leaf area is highly correlated with the total dry weight. A simple prediction equation was derived to estimate the total leaf area based on the linear measurements of 2nd and middle leaf and the total number of leaves. The coefficient of predictability of leaf area based on this equation was found to be very high (90 – 94%).

Cashew Research in Karnataka

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Karnataka ranks fourth in area (34,000 ha) and second in production (14,000 tons). Comprehensive research work on cashewnut was started in Karnataka, with the establishment of Central Cashew Research Station at Ullal in June 1953, in the erstwhile Madras State.

Systematic floral biology studies carried out at this station showed that the peak anthesis was between 9 and 11 a.m. and anther dehiscence commenced at 10 a.m. The cashew pollen remained viable for 48 hours.

Nursery practices relating to raising of seedlings have been standardized and the method of vegetative propagation through air-layering has been perfected. Recent studies have shown that cashew could be propagated by cuttings treated with growth regulators.

Among the seedlings progenies of 111 high yielding trees selected through a survey of all cashew growing areas, ten high yielding selections have been made of which selection 3/67 Guntur, Andhra (20.97 kg), 3/108 Gubbi, Mysore (19.11 kg) and 9/2 Nileshwar, Kerala (19.6 kg) have been outstanding. From among the clonal progenies of 116 selections established in 1956, progeny No. 4/117 has given maximum yield.

The results of root distribution studies of layers, seedlings and grafts show that layers have a stronger and better formed root system capable of withstanding high wind and drought like the seedlings.

Studies on effects of different systems of training have indicated that cashew needs no particular training and yield was adversely effected by the leader or modified leader systems of training.

Root Studies in Cashew Air-Layers and Seedlings

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This study was conducted at the Cashew Research Station, Vellanikkara, to find out the comparative development of the root system in cashew air-layers and seedlings and also the canopy spread of cashew plants of different age groups and its correlation with root spread in laterite soil. There was no appreciable difference between the length and depth of roots of layers and seedlings. The canopy spread showed a positive correlation with root spread. This may be used in determining the zone of fertilizer application and spacing in cashew. There was no detectable difference in height, girth and spread of canopy of seedlings and air-layers.

It was also found that in hard soils of 3–40 cm depth, the tap root grew only to the depth of the soil. Even in deeper soils, the tap root could not be distinguished from the root system of the layers.

ENTOMOLOGY AND PLANT PATOHLOGY

Bio-Ecology of *Helopeltis antonii* Sign. Infesting Cashew Trees

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The tea mosquito bug *Helopeltis antonii* Sign. is the most serious pest of cashew trees in South India causing inflorescence blight and drying up of tender shoots and nuts.

The bio-ecology, morphometrics and the nature of damage have been studied in the Cashew Research Station, Kerala Agricultural University, Vellanikkara and in the laboratories of the Department of Entomology from August 1977 to September 1978.

For biological studies, adults reared out from field collected nymphs confined on apical shoots of cashew seedlings of 6 – 8 months growth were used. For oviposition, pairs were confined on shoots and these were kept at 25 $\pm$ 1 °C in an air conditioned insectary. The embryonic and post embryonic developmental stages were studied at 28 $\pm$ 1 °C in the B.O.D. incubator.

In the adult field populations, females always predominated and during October 1977 – January 1978, the ratio of females to males ranged from 1: 0.49 to 1: 0.62. The pre-oviposition and oviposition periods last for 4 and 6 days respectively. The mean longevity of females is 6.5 days, while the male life-span lasts for 5.2 days only. The mean fecundity per female at 25 $\pm$ 1 °C is 31.15. The life-cycle from egg to adult emergence occupies 22.2 days at 28 $\pm$ 1 °C, the duration of the different stages being 7.3, 2.1 3.5, 3.2, 3.3 and 2.8 days for the egg and the nymphal instars I, II, III, IV and V respectively.

The adults and nymphs feed on tender shoots, tender foliage, floral branches, tender apples and nuts. On the lamina, nearly triangular, water soaked non-coalesing necrotic lesions develop around the veins as a result of feeding and the tissues eventually dry up leaving brownish patches. The symptoms on other plant parts are different, being characterised by necrosis of affected tissues followed by the exudation of a gummy substance around feeding punctures. The symptoms are more pronounced at higher temperature levels of 31 $\pm$ 0.5 °C. Periodical sampling of field populations of adults and nymphs did not reveal any associated parasitoids and pathogenic microorganisms. The occurrence of *Crematogaster wroughtonii* Forel (Myrmecinae: Formicidae : Hymenoptera) as a predator of the first and second instar nymphs of *H. antonii* has been reported for the first time.

Studies on the influence of three levels of constant temperatures viz., 25 ± 0.5 °C, 28 ± 0.5 °C and 31 ± 0.5 °C on the survival and progeny production of the insect have revealed that the optimum temperature for fertilization and oviposition was 25 ± 0.5 °C while for embryonic development and progeny emergence the temperature preferendum was around 28 ± 0.5 °C. The insects did not oviposit at 31 ± 0.5 °C.

Chemical Control of Cashew Leaf Thrips (*Rhipiphorothrips cruentantus* H.)

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A field trial was conducted at Regional Entomology Research Unit, Bapatla during August and September 1978 to find out the most effective and economic insecticide against cashew leaf thrips, *Rhipiphorothrips cruentatus* H. Sprays of phosalone and dimethoate at 0.05 per cent were found to be highly effective in the control of the pest even upto 15 days after spraying. Quinalphos at 0.05 per cent and malathion at 0.1 per cent gave more than 99 per cent mortality of the pest, 24 hours after treatment but, failed to protect the crop for more than a week. Sprays of other insecticides viz., BHC 0.1 per cent, endosulfan 0.05 per cent, chlorpyrifos 0.05 per cent were not effective in controlling the pest. Spraying with phosalone or dimethoate at 0.05 per cent is thus the most effective and economic control measure for cashew leaf thrips *R. cruentatus*, H.

Field Evaluation of the Efficacy of Four Insecticides in the Control of Tea Mosquito

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The adults and nymphs of tea mosquito *Helopeltis antonii* Sign. suck sap from the tender shoots, freshly emerged leaves, inflorescences, immature nuts and developing apples. The injury made by this pest results in drying up of the new flushes, giving scorched up appearance to the trees, shirivelling and falling of the immature nuts of different stages. The need for an alternative insecticide has often been felt in the past as sometimes endosulfan which is effective in controlling tea mosquito was not readily available in certain cashew growing areas.

An experiment was laid out in farm of the Central Plantation Crops Research Institute, Kasaragod, Kerala, India and it had run for three consecutive crop seasons from 1975–76 to 1977–78. The insecticides used in this trial included quinalphos, formothion, diazinon and endosulfan all at 0.05 per cent concentrations, applied as high volume sprays using ordinary rocker sprayers. Each treatment was replicated 20 times in a completely randomised design with single tree plots. Three rounds of insecticide treatments were done, at the time of emergence of new flushes, inflorescence emergence and fruit set, taking into account the trend of population build-up of the pest. The number of sample panicles per tree was fixed on the basis of the canopy size and the number of shoots all round the canopy. Observations on the number of inflorescences showing blight symptoms (partial or full), characteristics showing blight of tea mosquito infestation, were recorded from each of the experimental trees.

All the insecticide treatments were significantly effective and superior to control in minimising the pest infestation for all the three years. However, spraying of endosulfan 0.05 per cent recorded the least degree (17.7%) of inflorescence infestation as against 90.9 per cent in the untreated control plots. Endosulfan was followed by quinalphos and formothion which recorded 25.3 per cent and 26.0 per cent infestation respectively. Diazinon treatment recorded 34.1 per cent inflorescence infestation. Three rounds of spraying at the time of emergence of new shoots, panicles and fruit setting are necessary to bring down the tea mosquito infestation on cashew. Of the different insecticides tried endosulfan has given consistently better results, followed by quinalphos and formothion all at 0.05 per cent concentration.

DEVELOPMENTAL PROGRAMMES AND MARKETING

India's Imports and Exports of Cashew Products in International Market— An Analysis of Trends and Tendencies

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Cashew is one of the India's major foreign exchange earners and the second biggest dollar earner. Till recently, India has had virtual monopoly in the world supplies of both cashew kernels and cashew nut shell liquid. But with the development of domestic industries in some of East African countries, India would increasingly begin to face stiff competition from these sources in her export market. All the cashew that is exported from India is not grown within the country itself. In fact, nearly three fourth of it is imported from Mozambique, Tanzania and Kenya. About 177,289 tons of raw cashew were imported by India, whereas its exports of the same were to the tune of 57,976 tons in 1974. Though, India holds a virtual monopoly in cashew trade, supplying more than 90 per cent of the World's demand for cashew, she has to depend heavily on raw cashew imports from abroad.

An attempt is made to analyse the trends of India's imports and exports of cashew products in international market covering a period of 18 years based on the data from the Cashew Export Promotion Council, Cochin. India's cashew exports abroad were divided into six zones, viz., American, European, West Asian, South East and Far East Asian, African and Oceanic zone. India's exports to U.S.A., Canada, U.S.S.R., Netherlands, U.K., Hong-Kong, Japan and Australia were estimated. The following linear function was used to depict the trends of imports and exports of cashew. $Y = a + bx$, where Y = quantity in thousand tons, x = Year and a = constants.

In addition to domestic produce, India imported raw cashew from other countries like Tanzania, Kenya, East Africa, Tanganika, Mozambique, etc. besides many other small countries. The total imports which stood at 97 tons valued at Rs. 7.3 crores during 1957 rose to 177.8 thousand tons amounting to Rs. 40.79 crores by 1974. Though the increase in the quantity imported during 1974 was less than double to that of 1957, the increase in value was as much as six times. This differential increase in quantity and value were evidently due to ever increasing prices of the raw nuts. As against an average

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price of Rs. 4,260 per ton of raw nuts in 1957, the price rose to Rs. 18,000 per ton by 1974. During 1968, the imports of raw cashew was maximum. There was a setback in the imports of raw cashew from other countries during the years 1959 and 1960. Though the quantity imported was fluctuating the price of the raw cashew was ever increasing. The regression coefficient of imports by India was positive which indicated that India was importing 5,240 tons of raw cashew nuts every year.

The quantity of export of cashew from India was only 34,600 tons amounting to total earnings of Rs. 14.73 crores in 1957 as against 58,000 tons with total earnings of Rs. 104.68 crores in 1974. The quantity of export of cashew kernels from India was increasing except during the years 1964, 1966, 1970 and 1973, though the value was ever increasing. Eventhough the difference in the quantity exported during the years 1973 and 1974 was very small (900 tons), the increase in the value of the product exported during that period was quite high (nearly Rs. 30 crores). Though the quantity recorded meagre increase of about 68 per cent, the value earnings recorded a staggering increase of about 610 per cent between 1957 and 1974. The un-corresponding differential increase in quantitative exports and value-realisation was mainly due to the steady increase in prices from one year to another. The total exports by 1975 amounted to about Rs. 118 crores, whereas the net foreign exchange earnings of India amounted to Rs. 81.5 crores. U.S.A, U.S.S.R., U.K., Canada, Australia, Netherlands and Hong-Kong were the important countries among many more which were importing India's cashew products. American zone was the major importer of India's cashew products, that was 33,106 tons amounting to about 55 per cent of the total exports upto 1971. Later European-zone emerged as the chief importer of Indian cashew, particularly U.S.S.R., importing a major protion of 58 per cent of the total exports. American-zone was thus relegated to the second position followed by South-East and Far-East Asian, Oceanic, West Asian and African-zones. Export of kernels was increased by nearly 1,600 tons yearly. The main importers of Indian cashew were U.S.S.R., Canada and Australia with positive regression coefficients, importing 1,500, 180 and 40 tons respectively every year. The regression coefficients of U.S.A. and U.K. were negative; which suggested that these countries were importing less quantity of 440 and 90 tons respectively every year. The regression coefficient of European-zone was high followed by South-East and Far-East Asian, Oceanic, West Asian, African and American-zones. The values of elasticities for American and African-zones were negative which indicated that the trend of exports of cashew kernels decreased by 260 and 36 tons respectively every year. The exports to European, Asian and West Asian zones were increasing by 1,560, 177 and 280 tons respectively every year, whose coefficients were positive.

APPENDIX

STATUS REPORTS FROM DIFFERENT COUNTRIES ON CASHEW GENETIC RESOURCES

India

Cashew is grown over 4.0 lakh ha with an annual production above 1.7 lakh tons. Cashew was introduced into Goa region and on the Malabar coast during the sixteenth century by the Portuguese. These two places are presumed to be the Centres of the disperal to the other parts of the country. It is most likely that the original introductions were nuts from only few trees and thus today we have very limited genetic base in the country. This may be the probable reason for the low variability which is seen in cultivated cashew. However, due to the inherent heterozygosity variability is observed with respect to plant canopy, leaves, flowering period, proportion of male and bisexual flowers, percentage of fruit set, size, shape, colour, taste and astringency of apple and size, shape and specific gravity of nuts.

There are no reliable records of introductions of cashew germplasms in any of the research centres where the assemblages are being maintained. The present collections are the seed progenies of the original introductions made four centuries earlier. Attempts to characterise the available variability and catalouging is only recent. Collections are now being maintained at (i) Bapatla (22 Exotic and 157 Indigenous), (ii) Vridhachalam (8 Exotic) and 169 Indigenous), (iii) Vengurla (116), (iv) Vittal (163), (v) Mannuthy (39 Exotic and 151 indigenous).

N.M. Nayar
C.P.C.R.I. (ICAR)
Kasaragod, India

Australia

Australia has no commercial cashew production but an attempt was made in 1963 to establish one in the Northern Territory. The project was abandoned in 1968 but many of the trees still remain and could be useful sources of drought tolerance.

Following a visit by Mr. David Russell the Queensland Department of Primary Industry established a collection of 37 accessions of cashew from a very wide range of producing countries and grew them at the Kumerunga Research Station, Cairns. Because of the severe incidence of tea mosquito type insects they abandoned any attempt to establish an industry and passed the seed to the Department of the North West in Western Australia where the collection is now being grown at Broome for commercial evaluation.

Australia has an active programme of plant introduction from Brazil and could be interested in participating in cashew collections from that region as well as elsewhere. My Department would be anxious to exchange seed or budwood with other countries.

In addition to the international collections hundreds of individual tree are being grown as ornamentals throughout the north-west of Western Australia and the north of the State of the Northern Territory. Seed of these has been collected for commercial evaluation at Broome in the north of Western Australia. The above areas are in the dry tropics and many of the fine trees growing under natural rainfalls as low as 800 mm could be of value as sources of drought resistance.

A.J. Millington,
Perth,
Western Australia.

Malaysia

Since 1965, conscious and unconscious introduction of cashewnut germplasm has been done in Malaysia. The principle agents for germplasm introduction are the Department of Agriculture, Malaysia and the Cashewnut Industry of Malaysia (CIMA), a subsidiary of Food Industry of Malaysia (FIMA). Thus far, seed materials have been obtained from Tanzania, Kenya, Malawi, Mozambique, Indonesia, Vietnam and India. Local materials have also been collected. Selection for high yield has been done by Malaysian Agriculture Research Development Institute (MARDI). A total of 16 accessions are available. Out of these C 11, F 793, F 2070, and F 696 are outstanding selections. Partial description of these selections have been done by MARDI. Further systematic selection is being carried out by MARDI and CIMA.

Chai Tiang Bian
(*MARDI*) *Malaysia*
Lim Kim Lu
(*FIMA*) *Malaysia*

Sri Lanka

Cashew was introduced to Sri Lanka by the Portuguese at the same time it was introduced to India by them. Since recently we have taken some interest in cashew and development work by the government as well as by private individuals has begun. It is grown in the sandy areas bordering the sea coast in the dry zone of Sri Lanka.

We have the greater part of the annual rainfall, which varies from 85–125 cm during the north east monsoons, which occurs in Sri Lanka between mid-October to mid-January. The temperature in the cashew growing areas vary from 26–29 °C and the relative humidity is 60–80 per cent throughout the year.

The Govt. of Sri Lanka has created the Sri Lanka Cashew Corporation to handle the development of cashew in area as well as processing and marketing. Now, cashew is grown in the north western coastal areas and the eastern coast in sandy and red yellow laterite soils.

Old established trees that are found in Sri Lanka, show a marked difference in the plant characters as well as yield of the nuts from the east coastal belt to that of the west. Since 1974, we have started a systematic selection of seeds for propagation purposes from selected mother trees based on the morphological characters of the plant (primary selection), floral biology and resistance to pests and diseases (secondary selection), quality and quantity of nuts and apples (final selection). From these selected mother plants, we have started to do vegetative propagation, but due to heavy mortality in the field, the major propagation method is still the seed. Among the vegetative propagation methods, air layering is found to be the best method.

We have also set up in the Konduchchi Cashew Plantation (which is in the north west area) an exotic germplasm collection for future studies. This collection has seeds obtained from India, Trinidad, Tanzania. At the moment and we are trying to obtain seeds from other countries also. Of the exotic varieties so far studied we find the Trinidad varieties giving high yields, but it is susceptible to pest attacks. We are also doing hybridization work.

K. Jeevaratnam,
Cashew Corporation of Sri Lanka,
Kondachchi Cashew Plantation,
Chillawaturai, Sri Lanka.

Philippines

Cashew was introduced into the Philippines during the early years of the Spanish rule. Since then, it has rapidly spread and become well naturalized in many places in the country. In 1977, there were about 3760 hectares planted to cashew producing 4,742 tons of raw nuts from 422,500 bearing trees. The three leading cashew-producing regions are Southern Jagalog (2460 hectares), Ilocas (650 hectares) and Central Luzon (390 hectares). Most plantings are found in backyards with few well-managed orchards in the islands of Palawan and Cuimaras.

In recent years, the national government has placed vigorous emphasis on the development and production of non-traditional export crops to help country reduce its trade deficit. Among agricultural crops, fruits appear to be very promising export commodities. The country is already exporting banana, pineapple and mango. Because of its multitudinous economic uses, the country feels that it can also develop cashew as an export commodity utilizing vast land areas having only marginal soils.

The first basic requirement in the development of a crop commodity is the availability of outstanding varieties. In the case of cashew, the Philippines does not have any varieties to speak of, but it has numerous seedling trees from which selection of promising trees could be made. Thus, the National Plant Genetic Resources Laboratory of the Institute of Plant Breeding has initiated in 1976 the selection of outstanding trees.

For preliminary evaluation, all cashew trees whose kernels weigh at least 2 grams each are tentatively considered promising. To date, the Institute has identified some 60 promising trees. These promising trees have been properly labelled and are now being thoroughly evaluated for yield and quality of nut and apple and other horticultural attributes. They are also being screened for their response to vegetative propagation and reaction to pests and diseases.

Evaluation and selection of other existing trees are being undertaken on a continuing basis, and the local collection will be enriched by introducing promising selections from other cashew producing countries.

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