Journal of Plantation Crops 13 (1): 1–10 June, 1985

PLANTATION CROPS RESEARCH - 2000 AD*

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Patrons and members of ISPC, ladies and gentlemen,

I had been fortunate to be associated with the activities of the Indian Society for Plantation Crops (ISPC) right from its birth in 1971 as its founder President and later as the elected President for two terms. During the Fifth Annual Meeting of the Society, I had reviewed the status of the plantation crops industry as it existed then and the areas requiring immediate attention from researcher and developmental agencies (Bavappa, 1976). Much water has flown under the bridge since then. Research break-throughs have been achieved in tissue culturing of coconut and on the etiology of root (wilt) disease. Substantial increase in production and productivity has been achieved in some of the plantation crops (Table I).

There is no difference of opinion that the above increase in production and productivity is a clear indication of the dividents that we have started getting from the R & D efforts on these crops. All the same in some of the important plantation crops such as coconut, pepper, and cashewnut the production and productivity are stagnant or even declining. The first responsibility on all those connected with this

Table I. *Production and productivity of plantation crops*

Crops	1970 – '71		1975 – '76		1982 – '83	
	Production ('000 t)	Productivity (kg/ha)	Production ('000 t)	Productivity (kg/ha)	Production ('000 t)	Productivity (kg/ha)
Tea	435.5	1221	487.1	1341	569.6**	1491
Coffee	109.0	799	84.0	490	152.1**	720
Rubber	92.2	454	137.8	614	152.0**	800
Coconut*	6077.7	5813	5829.4	5449	5664.3	5088
Arecanut	141.0	843	160.0	901	184.5	1024
Cashewnut	176.7	584	171.4	465	195.8**	407
Pepper	26.2	218	28.5	235	28.5	257
Cardamom	3.1	41	3.1	31	8.8	85

* Production in million nuts and productivity in number of nuts/ha
** Earlier figures repeated

* *Presidential address delivered at the 12th Annual General Body Meeting of the Indian Society for Plantation Crops.*

industry is to remedy this alarming situation.

The ISPC has been constantly endeavouring for the overall growth of the plantation crops industry. Interaction has been made possible through the Plantation Crops Symposia (PLACROSYM) which has fostered better interaction and understanding among the community of scientists working on these crops. The International Symposium on Coconut Research and Development and on Cashew and National Seminars on different plantation crops were all worthwhile efforts in crystallising policies and programmes towards increasing productivity at all levels.

It is now time for us to plan our strategies upto the 2000 AD and if possible even for the 21st century. The projected requirements of different plantation crops at 2000 AD are given in Table II.

Table II. *Estimated demand for plantation crops in India in 2000 AD*

Crop	Demand in 2000 AD (in '000 tonnes)
Tea	1400
Coffee	260
Rubber	750
Black pepper	60
Cardamom	7
Cashewnut	360
Coconut	12000 (million nuts)

Most investigators and leaders in agriculture expect that a revolution in agriculture through genetic engineering may take longer than 10–20 years since several break-throughs are required. As such, for achieving the above targets, research on evolution of new high yielding varieties with tolerance to diseases and environmental stresses, adopting approaches and involving the expected break-through in some of the biological processes such as transfer of symbiotic nitrogen fixing capability, C_4 mechanism of photosynthesis, reduction of loss due to respiration etc. have to be our major concern upto 2000 A.D.

1. Basic change in research strategy

Research has little relevance unless the results obtained therefrom contribute to social benefit. It has to be admitted that the on-going research efforts are isolated in nature and in many cases either not sufficiently important in relation to production or is not carried through to a stage of effective transfer to the field. This will mean that in future while planning research, a variety of factors and their likely interactions should be taken into account. Computerised inventories of the following interacting factors are therefore a prerequisite for adopting such a strategy:

1.1. Human resources

a) The population growth and fast changing socio-economic conditions do affect the social structure, outlook etc. of the society considerably. Landless labour, farmers with marginal, small and large holdings, tribals etc. are all specialised clientale requiring different technologies and approaches. As such the researchers should have an idea of the strata of the population for whom the research is aimed at. A look at the holding size distribution of some of the plantation crops would be relevant (Table III).

Table III. *Holding size distribution (%) of plantation crops*

Holding size	Rubber	Cardamom	Coconut
2 ha and below	87.4	68.0	98.8
2 to 4 ha	7.9	17.3	
4 to 20 ha	4.3	13.2	1.2
20 to 40 ha	0.2	0.9	
Above 40 ha	0.2	0.6	

When the proportion of farmers with small holdings predominate these crops, technology development has to reckon this important social factor.

b) It is equally important that for an identified research project disciplines to be involved are determined and availability of trained and competent scientists to handle the project are ascertained.

c) The mechanism required for the transfer of technology being developed should also receive attention from the beginning. The agencies and type of man power suited for this are to be identified for initiating action to develop the same.

If a total picture on the above are available, it will be possible for deployment of man power, continued interactions and develop an appreciation among the researchers that their efforts are likely to benefit at least those sections of the society for whom the programmes have been planned. It is also necessary that even for specific problems of the nature of pests and disease control, factors such as the continued availability of the chemical is to be ensured before initiating research.

1.2. Present level of understanding areas of production

For a productive research the starting point has to be based on what has already been done not only in that particular field but also in the related areas which should be critically analysed by the research group and the work planned. The available research results should, therefore, be summarised and appropriate retrieval systems developed.

1.3. Genetic resources of animals, plants and microbes

Since exploitation of genetic diversity will continue to play vital role in enhancing/stabilising production, an inventory of the genetic resources of animals, plants and microbes related to plantation crops industry indicating conservation and *in–situ* centres of both indigenous and introduced materials indicating the possible/potential use of each must be prepared urgently.

1.4. Input requirement and constraints

One of the major reasons for the limited flow of research results into the farmers' fields is the lack of understanding of the input needs and constraints that the farmer/extension agency will have to face if a given technology is to be adopted. The intrastructural requirements such as adequate supply of an improved variety through well established seed gardens, agencies suited for taking up the transfer, capital required and method of making available the same etc. are all areas to be looked into.

The advantages of computerising such information are obvious. However, what is more important is whether answers/predictions can be obtained from a total analysis of the likely interacting factors and whether a research programme is likely to be socially beneficial and if so when and under what circumstances. If this answer could be provided, fixing priorities in research is bound to be much more meaningful.

2. Upgrading of average yields

2.1. Multi-disciplinary revolution

Yields have not reached a plateau. The green revolution achieved in annuals (wheat, rice and corn) has been by and large the function of improved varieties cultivated under a set of limited conditions over specified areas. Still, the average yields of not only these crops but that of many others are far less than the averages realised by a number of farmers. A multidisciplinary revolution in agriculture with greatly increased crop productivity is just around the corner.

If we are to integrate the various independent pieces of know-how which already exist on how to improve crop yields into a unified or integrated system, substantial increases in production are possible.

The following is the effect of management system on increasing crop yields (Table IV).

Table IV. *Yield of crops*

Crop	Yield in metric tonnes/ha	
	Average	Best realised
Wheat	2.5	20
Potato	37.0	100
Soyabean	2.0	7.5
Corn	6.8	22.5
Coconut	5000*	19400*
Arecanut	3.0	9.6

* Nuts per ha

The secrets of attaining 20 tonnes per hectare of corn are inputs such as an appropriate hybrid seed, a population of 90,000 plants, correct planting date, eliminating soil compaction, plenty of soil organic matter, 440 kg of nitrogen, 220 kg of phosphoric acid and 440 kg of potash, sufficient and continued availability of soil moisture, control of weeds without injury to plants and protection against pests and diseases. If soil moisture becomes limiting, then the computer indicates the need for withholding some of the nitrogen fertilizer. While all these factors are equally relevant to plantation crops also, soil depth, size of pits, filling the pits with organic matter, healthy and properly aged seedling etc. are some of the additional points requiring special attention for breaking the present yield barriers.

The exciting aspect of simultaneously overcoming several limiting factors to crop production is that additive effects are experienced (Wallace, 1984). Correcting two limiting factors alone may result in a 20% yield increase for each. When both are corrected together the combined yield increase is more than 40%; it can be 44 or more ($1.20 \times 1.20 = 1.44$). When six, eight, ten or more limiting factors can be corrected simultaneously the total effect can be staggering. Often the combined effect of two corrected limiting factors is a synergism (Putnam and Penner, 1974). The combined effect then is much greater than the sum of the parts. Yields go up very rapidly with synergistic responses. An integrated approach to overcome limiting factors on sugar cane growth increased yield of the cane almost five times (Hussain, 1982). At this level inputs which normally give smaller incremental return, will start giving higher responses.

Much improvement is still possible especially if the disciplines work together to eliminate more of the limiting factors. Examples of recent works to improve yields by overcoming multiple limiting factors have been reported by a number of workers (Anderson and Balser, 1983; Brann and Alley, 1983). This should therefore, become a great research goal. Integrated inter-disciplinary experiments to test the additive and synergistic effects of available production know-how and for obtaining information on critical areas of interaction for a computerised monitoring of the crop production will be greatly rewarding and should enable the easy accomplishment of the projected requirements of 2000 AD.

2.2. Tissue culture

Genetic variability of a population sets limitation in obtaining higher yields in the population unless efficient clonal multiplication techniques are available for the large scale propagation of any outstanding high yielding or otherwise desirable naturally occurring or synthesized plants. In coconut while the average yield of WCT is 60 nuts/palm/year, elite single palms yielding 470 nuts and single D $\times$ T hybrid palm giving 180 nuts/year under rainfed conditions are available. There is no better method immediately available for breaking the yield barrier than adopting tissue culture technique under such situations provided adequate care is taken to include a wider genetic base in such materials used for multiplication. Where somaclonal variation is desired to be exploited a callus pathway and in cases where genetically uniform clonal populations are to be generated from elite selections, direct embryogenesis and plant formation will be the useful tools. Research on the biochemical control of the process of somatic embryogenesis in crop plants where the technique is rewarding should be a priority area.

2.3. Manipulation of physiologic parameters

The overall conversion efficiency of crop plants depends to a great extent on the rates of dark respiration and photo-respiration exhibited by them. Althouth a high rate of dark respiration reflects better growth of the plants, some crops use large portion of the photosynthates for their maintenance through this mechanism. In C_3 plants intensive search for crop varieties/individual plants which have higher efficiency in dark respiration as well as low photorespiration should be made so that the net dry matter production level is enhanced. Considerable efforts should also be made to locate C_4 system in individual plants among perennial species since some of them show outstanding yields which could possibly be due to C_4 pathways.

3. Biomass pathway

Calculation based on theoretical concepts have shown that the potential dry matter productivity of a crop in tropics under conditions of optimum management is 770 kg dry matter/ha/day which is equivalent to an annual biological yield of 281.05 tons/ha (Loomis and Williams, 1973). As against this, the estimated potential dry matter production in some of the plantation and other tropical crops (Corley, 1983) is given in Table V below.

Table V. *Estimated potential dry matter production*

Crop	Total dry matter production ($t\ ha^{-1}\ a^{-1}$)
Oilpalm	44
Coconut	51
Rubber	46
Cocoa	56
Cassava	64
Sago	64
Leucaena	60

The above yields are from monocrops. There are definitely methods by which the total biomass production per unit area in unit time can be enhanced through high density cropping system approach. In such a system it was also possible to ensure that the basic needs of food, fibre, energy, timber etc. are also generated by an appropriate choice of the constituent crops. Considerable income generation can also be ensured. Experiments conducted in Sri Lanka have shown that one such model involving over one dozen crops at a population density of 3606 plants/ha is capable of giving an income of over Rs. 46,000 per annum in addition to giving a variety of home needs and fodder for animals (Bavappa and Jacob, 1982). Recently a high density planting of constituent crops in coconut garden taken up at Kasaragod has over 13,000 plants/ha wherein the normal stand of coconut was only 175. The dry matter production in all these cases is yet to be estimated. All the same, it is expected that in view of the maximum harvest of solar energy through the canopies of different crops under multilayered system and better utilisation of soil mass, the productivity of biomass could be pushed higher. Such an approach has many advantages such as minimum requirement of tillage, continued returns and better economic stability, higher generation and recycling of organic matter and nutrients and better ecological balance. A highly multidisciplinary approach to understand crop compatibility, interplant competition, nutrient balance, moisture requirement, soil microbiological changes, ecological advantages, energy input and output, biomass production and economics of the systems involving annuals, perennials and animals in varying combinations is highly worthwhile.

4. Low cost technology

Most of the currently available technologies are neutral to scale but not to resources, thereby compelling the farmers to spend more on the inputs. Research should be oriented to developing technologies that do not cost much to the farmers.

4.1. Utilisation and conversion efficiency of Photosynthesis

While photosynthetic efficiency of a particular crop is important, conversion of solar energy through the photosynthetic apparatus of a crop community is more relevant in a tropical situation where mixed cropping patterns are being followed. Understanding of this conversion capability is a primary need.

4.2. Nutrients

Recent researches have shown that the ability of D×T coconut to exploit the native fertility of the soil as well as to use the applied nutrients is much higher compared to West Coast Tall (Table VI).

Research to unearth this capability of the plants will be most rewarding.

4.3. Moisture

The fact that no crop production worth the name is possible without moisture, has shifted the search for drought resistant plants to those capable of doing well under stress (low moisture availability). Since moisture and nutrients have high interaction and also in view of the fact that moisture availability become limiting atleast during certain periods of the year, search for stress tolerant varieties should receive priority.

4.4. Pest and disease resistance

Research on evolution of crop varieties with pests and disease resistance is most rewarding since the end result is a no cost technology. While search for resistance in the available populations should form part of any crop improvement programme, induction of resistance and transfer of resistant genes adopting DNA recombinant technique should be taken up.

4.5. Better adaptation to environment

An analysis of major U. S. crops shows that there is a large genetic potential for yield that is unrealised because of the need for better adaptation of the plants to the environments in which they are grown (Boyer, 1982). Evidence from native populations suggests that high productivity can occur in these environments and that opportunities for improving production in unfavourable environments are substantial. Genotype selection for adaptation to such environments has already played an important role in agriculture, but the fundamental mechanisms are poorly understood. Recent scientific advances make exploration of these mechanisms more feasible and could result in large gains in productivity.

Table VI. *Utilisation efficiency of nutrients*

		Nuts yield/palm		
		WCT	D×T	T×D
M0		23	31	17
M1		31	75	60
M2		67	76	61
			Nutrients (gms)	
Qty. of fertilizers to be applied to get 75% maximum yield.	N	1025	140	170
	P	1025	140	170
	K	2050	280	345

4.6. Biological fertilizers, nitrogen fixation and nutrient systems

Though the possibility of cheaper sources of nutrients through biological fertilizers and nitrogen fixation have been indicated this is yet to come to a level of commercial exploitation. While the pace of research in this area should be accelerated using modern biotechnology tools, a more relevant area of immediate interest is the nutrient addition and conservation through cropping systems. Research on relay and mixed cropping systems for improving their self generating and conservation capability with regard to nutrients is a high priority area. Cocoa mix cropped with coconut in double hedge system has been observed to add 50 kg N, 11 kg P_2O_5 and 35 kg K_2O/ha/year. Much higher efficiency may be possible by appropriate choice of crops and supporting them further with proper biological agents such as arbuscular vesicular mycorrhizae, Rhizobium, free living fixers for nitrogen etc.

4.7. Slow release fertilizers

Recent research has shown that in coconut grown in sandy and sandy loam soils, up to 80% of the applied nitrogen is lost by leaching. Importance of slow release fertilizers in this context is most relevant for reducing the fertilizer input.

4.8. By-product utilisation

A number of agricultural by-products if used in appropriate places can considerably bring down the cost of production. Coconut husk pith is ideal soil amendment for sandy soils. Rice bran and brewery waste in cattle feed could substitute wheat bran reducing the cost of production of milk by 35 paise/litre.

The research towards 2000 AD therefore, should not be simple trials but large experiments involving genotypes with variables for nutrients and moisture under an appropriate cropping system with a 'o' control and a large inter-disciplinary team working on atleast the more important parameters of production and their interactions.

Innovations for 21st century

1. Biotechnology research

Though considerable optimism is evinced in this area as a tool for enhancing production, it is evident that massive investment and expertise are required to achieve meaningful gains. Since very many easier approaches are still available at lesser cost for increasing production, it is only logical that these should be first researched. All the same of a plateau in yields is to come by the turn of century, methods for breaking this barrier should be available. It is in this context that biotechnology research particularly becomes relevant.

1.1. Root nodule symbiosis

The property of atmospheric nitrogen fixation is now limited to leguminous plants, among higher plant species. Monocotyledonous plants provide no confirmed instances of nodule symbiosis. Although some of these may be induced to participate in rhizosphere, nitrogen fixation which leads to large gains in nitrogen, nodule symbiosis is considered to be the most efficient. Recently some workers have considered the possibility of imparting a faculty for nitrogen fixation to higher plants themselves. Rhizobia have been successfully fused with tobacco protoplasts and these cells, when cultured on a suitable medium is expected to give a whole plant with nitrogen fixing ability. These findings open up new and exciting possibilities of obtaining hybrids between legumes and perennial monocots which will eventually lead to enormous saving in nitrogen fertilizers.

1.2. C-3 C-4 hybridisation

C-4 plants in general are the most productive, capable of producing high biomass and yield. Transferring a number of characters from C-4 to C-3 plants adopting normal breeding techniques have been done. However, transfer of the most important characteristic *viz.*, C-4 pathway has not been achieved. Cellular hybridisation and monocular transformation should enable the transfer of C-4 mechanism to C-3 background.

1.3. Other areas of interest

In perennial crops screening for resistance especially to virus, mycoplasma etc. is an exceedingly time consuming process today. *In vitro* culturing of pathogenic agents like mycoplasma and *in vitro* screening of the callus/embryoids obtained through tissue culturing technique should enable locating resistance much faster. In the case of disease problems like Root (wilt) and Thatipakka diseases of coconut, Yellow Leaf Disease of arecanut, research to standardise the basic technique should be undertaken. In this context, the possibility of developing a vaccine for the plant mycoplasma on a cross protection technique may not be viewed as stretching the imagination too far. As a long term practical measure of immunising millions of coconut palms this is worth heavy investment.

2. Breeding new strains of bacteria Biomass degradation

When biomass production pathway becomes a reality, the surplus dry matter can profitably be used only if the same is separated into fractions based on lignin, cellulose, hemicellulose etc. for further exploitation. Search for bacteria capable of such functions will have to be made and if required even evolved.

3. Sky farming

During the twentyfirst century, at least in urban areas and in some of the thickly populated tracts the pressure on land will necessitate farming in the air space, roof tops and for that matter any area available for growing plants without directly coming in contact with land mass. This calls for research on production technology for farming without soil in media which are light and which can keep moisture and nutrients in a continuously available form, structures to support such media in space, mechanisms to feed them and breed plants with canopies and root systems fitting into this. Air space factories should be virtually possible for many crops. Research in this area has to make some beginning.

4. Breakthrough research

Even in the entire biotechnology area there are critical phases, a breakthrough in some of which can revolutionise production. Methods to increase PAR conversion from its low level of 1%, microbial system to fix the air nitrogen in adequate quantities making farming independent of rapid nitrogen, a photosynthesis mechanism independent of plants etc. are some of the areas having far reaching implications in production. Research units manned by scientists who can commit themselves for such challenging areas should be thought of.

Research in 2000 AD while is challenging should also be novel and ingenious.

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