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AGRONOMIC RESEARCH IN ARECANUT—A REVIEW*

K. SHAMA BHAT

Central Plantation Crops Research Institute
Regional Station, Vittal-574 243, Karnataka, India.

ABSTRACT

The work done and results achieved on the agronomic/management aspects of arecanut is reviewed. The studies relate to standardisation of nursery practices and field experiments to find out the long range requirements of the crop. Nursery trials have given sufficient information on the correct technique of raising arecanut seedlings. The long duration experiments have indicated the optimum cultural, spacing, irrigation and N, P, K requirements of the crop. The inter and mixed cropping trials have shown useful results.

I. INTRODUCTION

Research on improvement of arecanut (*Areca catechu* L) began as early as 1914. During that year, the Mysore Agriculture Department started a government farm at Marthur, in the Malnad area of Shimoga District, with the main objective of tackling the *koleroga* disease of arecanut. Experiments for improving the production through manuring and selection were also taken up at the Marthur Farm (Coleman, 1918). Unfortunately, the farm was closed in 1939 and the researches discontinued (Dorasami, 1956). Nambiar (1949), who made a survey of the arecanut crop in India, observed that no work on fundamental or agronomic aspects of arecanut had been made till then except developing certain measures for combating major disease of the palm. The first attempt to organise research on arecanut improvement and management was made by the erstwhile Indian Central Arecanut Committee, when the Central and Regional Arecanut Research Stations (presently, the Regional and Research Centres of the Central Plantation Crops Research Institute) were established in the late fifties. These research stations initiated and conducted a number of field experiments aimed at standardising nursery practices, and working out the nutritional and water requirements, besides tackling problems on soil chemistry, pests and diseases, crop physiology, and variety improvement. An attempt is made in this paper to review the work done and results achieved on the agronomic/management aspects of arecanut.

II. NURSERY PRACTICES

A number of trials have been carried out at the Central and Regional Arecanut Research Stations between 1956 and 1966 for standardising the nursery practices of arecanut. These included studies on criteria for selection of seednuts, media of sowing,

* Contribution No. 177, Central Plantation Crops Research Institute, Regional Station, Vittal.

spacing of seednuts, and shade requirements of nurseries.

In the experiment to determine the optimum maturity of seed nuts, no appreciable difference in germination percentage of nuts was observed in the nursery among seed nuts ranging in maturity from 9½ to 10½ months (Annual Report, CARS, 1964). Bavappa and Abraham (1961) worked out the extent and mode of variation in nut weight within each bunch of arecanuts. According to them, 25% of the nuts in a bunch are light. Heavier nuts gave higher percentage of germination and produced seedlings with greater vigour. The outturn of quality seedlings was also higher from heavier seeds. The lighter nuts gave 87% germination and heavier nuts 96% germination. Studies made in a bulk nursery revealed that the average germination was 95%.

The mean number of days required for commencement of germination and its completion were 53 and 94, respectively. About 2% of the nuts did not germinate, mainly due to embryo rot. The embryo was absent in 1.7% of the nuts (Bavappa, Patel, and Bhat, 1957). After germination, a few sprouts died due to physiological or other reasons. These accounted for 1.6% of the nuts sown. The conventional practice of the cultivators is to sow the seed nuts after allowing them to dry for a couple of days under partial shade. Bhat (1956) found that it was not necessary to dry the nuts after harvest, as sowing nuts immediately after harvest, gave equally good germination. He recommended sowing nuts as early as possible after harvest. Seed nuts do not require any pre-treatment, but sowing them instead soon after harvest, either in soil or sand and watering them daily or once in two days, give early and high percentage of germination (Annual Report, CARS, 1964). Farmers use several media like *muda* (straw bundle), baskets, soil, or sand for sowing seed nuts. However, Bavappa (1956) found that sprouting the seednuts in *muda* gave both lower germination (85%) and less establishment (76%) in the nursery as compared to 96% establishment in direct sown seed nuts in nursery beds. The growth characters also showed that seedlings of direct sown nuts were superior to those from other methods like sowing in *muda* or baskets. In parts of *malnad* and *maidan* of Karnataka, the arecanut bunches intended for seed purposes are lowered from the crowns of palms by means of ropes to avoid damage to nuts. However, Naidu (1961) found that lowering the bunches was unnecessary, since germination of seed nuts was not affected adversely when bunches were dropped to the ground.

Bavappa and Mathew (1969) reported that spacing given in the nursery significantly influenced the growth of seedlings. Seedlings planted at wider spacing show better shoot and root development. A spacing of 35-45 cm was considered to be optimum for a growth period of one year in the nursery. Arecanut sprouts and seedlings are very delicate and cannot withstand exposure to direct sun. Bhat (1970) observed that the mortality of sprouts was 19% in the open (fully exposed), while it was only 1% in partial shade, and only 0.13% in completely shaded nurseries. The height, girth, and number of leaves of seedlings in the open nurseries were significantly lower than those under shaded condition, (2.15cm girth *vs* 2.55cm girth), even though the percentage germination of seed nuts did not show any difference when sown either in the shaded or exposed nurseries. The outturn of quality seedlings was higher from shaded nurseries (Annual Report, CRARS, 1969).

Raising a live shade of *Coccinia indica* as an overhead *pandal* in the nursery was found to provide equally effective shade and protection as growing banana or erecting *pandal* (Annual Report, CRARS, 1967).

Paul (1960) recorded sowing seed nuts directly in 15 cm raised nursery beds of 130cm width, with a spacing of 30×30 cm in the sub-Himalayan region of West Bengal, since the harvesting season in the region coincides with the rainy season. He further found that *Boga medeola* and *Crotalaria angyroides* were satisfactory as shade plants for nurseries, since they thrived well under the low pH conditions of the region and were perennial in nature. Naidu and Mashalkar (1961) reported that *Sesbania aegyptica* was the best shade plant in the *maidan* areas of Karnataka. It is a quick growing perennial species and provides good side and top shades. It also could be pruned if necessary to regulate the shade.

Results of the trials carried out at Vittal showed that seedlings are ready for transplanting in the main field when they are 12-18 months old. Selected individual seedlings are preferably removed with a boll of earth for transplanting. Wrapping the base with the boll of earth in plastic sheet/bag could keep the seedlings in good condition during long distance transport (Annual Report, CARS, 1964). According to Appaiah (1970) raised beds into which sprouting arecanuts are normally transplanted 3 months after sowing can be replaced by polythene bags. He has listed the advantages of a polybag nursery which include a 15% reduction in seedling mortality.

III. ADULT PALM AGRONOMY

A number of long term field experiments, aimed at determining the cultural, spacing, manurial, and irrigation requirements of the crop were laid out at the Regional Station, Vittal and the Research Centres, at Peechi (central Kerala), Palode (South Kerala), Hirehalli (*maidan* part of Karnataka), Thirthahalli (*malnad* part of Karnataka), Mohitnagar (West Bengal), and Kahikuchi (Assam) during the late fifties and sixties. The results obtained from these are summarised below.

1 Age of Transplanting Seedlings. Seedlings of different ages are used for planting in the main field in different regions. The practice of sowing the nuts *in situ* as well as transplanting seedlings in nurseries twice or thrice prior to field planting are also in vogue. A study to determine the optimum age of seedlings at transplanting made at Vittal revealed that palms raised from seedlings of one to two year's age were more vigorous and flowered earlier than those raised from seedlings kept longer in the nursery. The cumulative yield of nuts from palms up to 9th year from sowing also showed the definite advantage of planting seedlings at the age of one to two years (Annual Report CPCRI 1971). The results obtained at Kahikuchi where a similar trial was in progress also showed that palms which were planted in the field when young (18 or 30 months old) were more vigorous than those which were planted when they were 42 months old (Annual Report CRARS 1971).

2 Spacing and Method of Lay Out on the Incidence of Sun Scorch. Arecanut palms are susceptible to sun scorch when exposed to the south-western sun. In order to know whether alignment of planting can minimise such damage, a trial with 3 spacings and 2 alignments of row was conducted at Vittal from 1960 to 1968. The spacing were: (1) palms spaced at 2.4m×2.4m in the square method; (2) palms spaced at 2.7m×2.7m in the square method; and (3) palms spaced at 3.6m in the quincunx method and the alignments (1) north-south direction and (2) at an angle of 20° north-south. The observations recorded for 5 years showed that there was no significant variation in the performance of palms among treatments.

The palms planted at 3.6m×3.6m in the quincunx method in the north-south direction showed lower incidence of sun scorching (Annual Report CRARS, 1971).

3 Optimum Spacing in the Field. Spacing experiments were initiated at Vittal in 1958, Peechi in 1960, Hirehalli in 1961, and at Kahikuchi in 1961-62. In all these centres, six spacings, *viz.*, 1.8×1.8m, 1.8×2.7m, 1.8×3.6m, 2.7×2.7m, 2.7×3.6m, and 3.6×3.6m, were tried. Observations recorded for 14 years at Vittal were summarized by Bhat, Leela, and Somaiah (1972). According to them, the various yield attributes like leaf fall, number of spadices produced per palm, percentage of spadices to leaf fall, number of female flowers per palm, and number of flowers set, were highly influenced by the spacing adopted. The number of leaves shed, and spadices and female flowers produced per palm invariably increased with increase in spacing (Table I). The number and weight of fruits harvested per unit area were maximum in plots with palms spaced at 2.7×2.7m (Table II). At Peechi, though

Table I. *The effect of spacing on the performance (leaf fall, spadices and female flower production) of areca palm (mean number/palm/year)*

Treatments (spacing) m	Leaf fall	Spadices produced	Female flowers produced	Flower set
1. 1.8×1.8	6.51	3.83	659.8	77.6 (11.8%)
2. 1.8×2.7	6.94	4.64	878.7	153.7 (17.5%)
3. 1.8×3.6	7.19	5.06	1025.4	199.2 (19.4%)
4. 2.7×2.7	7.53	6.01	1296.7	322.9 (24.9%)
5. 2.7×3.6	7.97	6.27	1289.0	356.5 (27.7%)
6. 3.6×3.6	7.78	6.14	1396.9	378.5 (27.1%)
F. Test	**	**	**	**
C.V. (%)	2.69	11.67	11.08	27.31
C.D. (P=0.05)	0.30	0.94	182.2	102.1

** Significant at 1% level of probability

Table II. *The effect of spacing on the cumulative yield of arecanut (for 7 years)*

Treatment (spacing) m	Yield/palm		Yield per plot (10.8 m×21.6m)	
	Nuts (No.)	Nuts (wet wt. kg)	Nuts (No.)	Nuts (wet wt. kg)
1. 1.8×1.8	312	10.67	17160	587.01
2. 1.8×2.7	662	22.01	21830	762.12
3. 1.8×3.6	968	33.21	21300	730.57
4. 2.7×2.7	1329	47.65	21920	1000.57
5. 2.7×3.6	1559	53.64	21840	750.97
6. 3.6×3.6	1649	57.57	16490	575.65
F. Test	**	**	*	**
C.V. (%)	34.25	33.16	26.46	25.73
C.D. (P=0.05)	440	14.77	6630	222.91

*Significant at 5% level of probability
**Significant at 1% level of probability

the general trend in the behaviour of palms under different spacings was generally similar to those at Vittal, there was no significant difference in yield (both in number and weight) per unit area between different spacings. However, the highest yield was recorded in 2.7×2.7m spacing (Annual Report, CPCRI, 1974). At Hirehalli, the number of leaves shed and the number of spadices produced per unit area decreased as the spacing given to palm increased. Maximum number of nuts per plot was obtained in spacing 1.8×3.6m closely followed by 2.7×2.7m. The weight of nuts was however maximum in 2.7×2.7m spacing followed by 1.8×2.7m spacing. The differences in the yield of nuts among 1.8×3.6m and 2.7×2.7m, and 1.8×2.7m were not significant (Annual Report, CPCRI, 1976). These results were slightly different in other years. At Kahikuchi, the number and weight of nuts harvested per unit area was highest in 2.7×2.7 m spacing which was significantly superior to those obtained from 1.8×1.8m, 1.8×2.7 m, and 3.6×3.6m spacings (Annual Report, CPCRI, 1977).

4. Cultural Operations. The cultural practices followed by the cultivators in different parts of India differ very much. Hardly any such operations are carried cut in Assam, parts of Kerala and West Bengal whereas in Karnataka and north Kerala the gardens are regularly cleaned of all weeds and hoed twice a year. According to Nambiar (1949), experienced arecanut cultivators all over the country are of the opinion that intercultivation increases the productivity of palms by 10-20%. In order to develop the optimum cultural practices for arecanut, experiments were conducted at the research centres in Peechi and Hirehalli during 1967–1975. At Peechi, were four treatments, (1) no inter-cultivation, (2) digging once a year, (3) digging twice a year, and (4) digging once in two years were under comparison, no significant differences were noticed between the treatments. The mean number and weight of fruits per palm per year in different treatment plots ranged from 321-374 and from 8.5—9.8 kg, respectively. At Hirehalli, digging the garden twice a year (in December and June) had given the highest yield of nuts as compared to the other treatmnets, (1) scything grass and weeds twice a year (June and December), (2) digging once a year (December) followed by scything weeds (June), and (3) scything weeds twice a year (June and December) and digging once in two years, Table III (Annual Report, CPCRI, 1976; Sannamarappa, Kumar, and Nagaraja, 1976).

Table III. *Effect of different methods of intercultivation on productivity of palms (Hirehalli, 1974–75)*

(Reproduced from Annual Report for 1975, CPCRI, Kasaragod)

Treatment	Yield/plot	
	Number of nuts	Weight of nuts (kg)
1. Scything grass and weeds twice a year (June and December)	4020.3	62.5
2. Digging once a year (December) followed by scything weeds (June)	3444.3	53.7
3. Digging twice a year (June and December)	7168.2	107.5
4. Scything weeds twice a year (June and December) and digging once in 2 years)	2113.8	29.9
Overall mean	4186.7	63.4
CD (5%)	2055.6	32.7

An observational trial to study the effects of different methods of raising arecanut gardens on hill slopes with three systems of planting, (1) planting on terraces made

along the contours, (2) planting on terraces made at the site of planting, and (3) planting on slopes not considering the contour, was carried out at Palode (Southern Kerala) under rainfed conditions during 1961–1974. Each of the above three treatments had nine sub-treatments, (*i*) no cultivation and no manuring, (*ii*) cultivation alone, (*iii*) manuring alone, (*iv*) clean cultivation and manuring once in two years, (*v*) clean cultivation and manuring once in six months, (*vi*) clean cultivation and manuring once a year, (*vii*) cover crop to be raised, cut, and spread plus manuring, (*viii*) cover crop to be raised, cut, and, incorporated by digging plus manuring, and (*ix*) permanent cover cropping and manuring. The final results showed that clean cultivation and manuring once in two years gave the maximum yield closely followed by cover crop (cut and spread) plus manuring. Palms planted along the contour recorded the highest yield. The production was minimum in palms planted on slopes without considering the contour (Annual Report, CPCRI, 1975).

Mulching arecanut gardens is an important operation practised by growers. A trial to compare four types of mulching materials, (1) chopped arecanut leaves, (2) Guatemala grass (*Tripsacum laxum*), (3) arecanut husk, and (4) dry leaves collected from forest lands, was conducted at Vittal. Soil moisture status studies made at different intervals after irrigation showed that the loss of moisture from the mulched plots was considerably lower compared to the plots with 'no mulch'. The moisture level in 'no mulch' plot was 10% ten days after irrigation. Under mulched conditions, the 10% moisture content was reached 18 days after irrigation. There was no appreciable difference between the different mulches (Annual Report, CRARS, 1969).

5. Irrigation. Arecanut is grown under both irrigated and dry conditions. In places with high subsoil moisture and in areas where the rainfall is well distributed, no summer irrigation is practised. Irrigation is given in areas with long dry spell from December to May. Nambiar (1949) opined that investigations would have to be carried out to find out whether arecanut could be grown as a dry crop in regions of heavy rainfall and also that the effect on yield of irrigated and non-irrigated conditions should be ascertained.

The depth at which the areca seedlings are planted depends upon the nature of the soil, the depth of water table, and topography of land. In order to determine the effects of depth of planting seedlings and frequency of irrigation on the performance of areca gardens experiments were initiated at Peechi in 1962, Hirehalli in 1963, Mohitnagar in 1962, Kahikuchi in 1964, and Vittal in 1966. At Peechi, all irrigation treatments led to substantial yield increases, the 3-day interval being better than 6 and 9 days intervals (Sadanandan, 1973). Similarly, with regard to the different depths (30, 60, or 90 cm) of planting the yield increased with higher depths of planting. According to him, the water requirement of arecanut during the four dry months was 82.5 cm. At Vittal, where four intervals of irrigation, 5, 10, 15, and 20 days and three depths of planting, 30 60, and 90 cm, were tried, irrigation at closer intervals of 5 and 10 days was superior throughout. But, with regard to depth of planting, the results were not consistant, though the palms planted at 90 cm depth were performing better than the shallower planted. The irrigation schedules were modified in 1973–74 and the treatments are now based on cumulative potential evaporation (CPE). The results are in favour of 30mm depth irrigation when the CPE is 30mm. At Kahikuchi, where three intervals of irrigation, *viz.*, 7, 14, and 21 days with no irrigation and three planting depths, *viz.*, 15, 30, and 45 cm, were tried the closer

intervals of irrigation, namely, once in 7 and 4 days, showed superiority over irrigation once in 21 days or no irrigation. Depth of planting produced no significant influence on the performance of palms. At Hirehalli, where again, four intervals of irrigation (5, 10, 15, and 20 days) and three depths of planting (30, 45, and 60 cm) were under comparison, there was no significant influence of any of the treatments on the performance of the palms (Annual Reports, CRARS, 1949, 1970, 1971; Ann. Repts. CPCRI, 1971, 1972, 1973, 1974, 1975, 1976, and 1977). At Palode (south Kerala), where arecanut palms are normally not irrigated, irrigation increased the yield by 2-3 times (Annual Report, CPCRI, 1972.

6. Manuring. Iyengar (1956) reported the results of manurial experiments conducted for 16 years during 1920 to 1936 at the Marthur Farm, Karnataka. According to him, the indications in general were that a garden once brought to good yielding condition may be manured once in 3 years, and that an yield of over 876 kg can be obtained by an application of 56.0 kg nitrogen, 84.0 kg phosphoric acid, and 112.0 kg potash per hectare using groundnut oil cake as a source of nitrogen.

In the 1950's, the erstwhile Indian Central Arecanut Committee had carried out a series of simple manurial trials in the cultivators' fields (Lakshmanachar, Biddappa, and Paulose, 1966). The experiment was conducted in the sub-montane and coastal regions of Kerala and Karnataka and plains of Karnataka, West Bengal, and Assam. The N, P, and K fertilizers were ammonium sulphate, superphosphate, and muriate of potash, respectively. The levels of nutritents added were N at 22.7 and 45.4 kg, P_2O_5 at 18.1 and 36.3 kg, and K_2O at 34.0 and 68.0 kg per 500 palms. The fertilizers were applied for three years, 1961–62 to 1963–'64. In Kerala, the treated plots in the sub-montane regions, gave on an average 20% and in coastal regions 11% increased yield during the experimental period, while during the post-experimental period, the increase in the mean yield in the treated plots was 52% for sub-montane and 24% for coastal regions. In the sub-montane region of Kerala, application of 22.7 kg of N, 18.1 kg of phosphoric acid, and 64.0 kg of potash for 500 palms was found to be economical. In the coastal regions of Kerala, and Karnataka, 22.7 kg of N, 18.1 kg of phosphoric acid, and 34.0 kg of potash for 500 palms was economical.

Comprehensive manurial experiments to determine the manurial requirements of areca palms were laid out under different agro-climatic conditions at Vittal, Hirehalli, Peechi, Mohitnagar, Kahikuchi, and Palode under the Central and Regional Arecanut Research Stations (present Regional and Research Centres of CPCRI) from 1961. In all the centres, except Mohitnagar, the treatments consisted of N at 0, 50, 100g; P_2O_5 at 0, 40, 80 g; K_2O at 0, 70, 140, g and green leaf at 0, 7, 14 kg per palm. At Mohitnagar, treatments consisted of N at 0, 100, 200 g, P_2O_5 at 0, 40, 80 g, and K_2O at 0, 140, 280 g per palm as main treatments, and lime at 0 and 1 kg per palm as sub-plot treatment. At Vittal and Peechi, the doses were revised in 1971 to include higher levels (double the original levels) of nutrients. At Peechi, the revised doses were tried using lime as a sub-plot treatment. N and green leaf in the original levels increased the yield of nuts significantly over zero levels at Vittal, Hirehalli, and Kahikuchi. At Vittal, though, there was increase in yield at higher levels of N (in the revised levels), the difference was not significant. The effect of green leaf application on yield of nuts was significant in most of the years and the maximum yield was obtained in the highest level of green leaf (21 kg per palm). Effect of K on number and weight of nuts was significant

at Mohitnagar and Kahikuchi. At Mohitnagar, lime at 1 kg per palm showed adverse effects on growth and yield characters (Annual Reports, CPCRI, 1969–1977). The results of the trial with the original levels of fertilizers carried out at Peechi were reported by Sadanandan (1972). According to him, nitrogen and green leaf application significantly and individually increased height, girth, and leaf production while potash significantly increased only height and leaf production. N at 100g and K at 140g per palm individually increased the production of spadices and percentage of spadices to leaf fall, nut production, and its relative weight significantly. N at 100g per palm significantly induced earliness in bearing. The influence of P was not significant on any of the characters studied except on an initial increase of height and percentage of spadices to leaf fall. Green leaf at 14 kg per palm significantly increased spadices production, percentage of spadices to leaf fall and relative individual weight of nuts. In the revised levels response to green leaf alone was significant. Green leaf at 21 kg per palm gave significantly more number of nuts than green leaf at 7 kg per palm (Annual Report, CPCRI, 1976). An experiment to determine the effect of applying fertilizers to supply N, P, and K in organic and inorganic forms on the performance of arecanut was in progress at Vittal during 1963–'69. The treatments consisted of (1) N, P, and K (25, 25, and 40 kg, respectively for 500 palms per year) in organic form during 6-15th year, (2) N, P, and K in inorganic form during 6-15th year, (3) N, P, and K in organic form during 6-10th year and then in inorganic form till the 15th year, and (4) N, P, and K in inorganic form during 6-10th year and then in organic form till the 15th year. The yield data for the various years showed no significant difference between the treatments (Annual Report, CARRS, 1971).

Another experiment to determine the effect of application of fertilizers in split doses was carried out at Peechi during 1968–1975. There were six treatments, (1) N, P, and K full dose in one application in September, (2) N, P, and K in two instalments in September and January, (3) N, P, and K three instalments in September, January, and April, (4) P and K in one dose in September and N in two instalments in September and January, (5) N and P in one dose in September and K in two instalments in September and January and (6) P in one dose in September and N and K in two doses in September and January. The full annual dose in all the treatments consisted of 100g N, 40g P_2O_5, and 140g K_2O per palm. Pooled analysis of the yield data (Table IV) showed that the treatment effects did not differ significantly (Annual Report, CPCRI, 1976).

Table IV. *Effect of fractional application of fertilizers on yield of arecanut (Peechi,* 1969–1975)

(Reproduced from Annual Report for 1976, CPCRI, Kasaragod)

Mean/palm/year

Treatment	Number of nuts	Weight of nuts (kg)
1. NPK in one application	328	10.7
2. NPK in two applications	337	9.2
3. NPK in three applications	333	9.7
4. PK in one dose and N in 2 doses	364	9.8
5. NP in one dose and K in two doses	334	9.4
6. P in one dose and N Kin 2 doses	347	9.9
SE for treatments	84.46	00.92

7. Inter and Mixed Cropping. The practice of growing subsidiary crops in arecanut gardens is fairly universal and has been practised by arecanut farmers since long.

The inter and mixed crops that are grown vary widely in different parts of the country. The practice of multiple cropping has assumed much relevance in the present context of increasing the productivity from unit area of land. With the establishment of the Central and Regional Arecanut Research Stations, a number of experiments to study the role of inter crops in arecanut gardens were commenced from 1963–64 (Annual Report, CARRS, 1967). Bhat and Nambiar (1972) reported that under the shade prevailing in arecanut gardens, crops like arrowroot and pineapple grew satisfactorily and did not adversely affect the arecanut palms. Khader and Antony (1968) stated that experiments conducted at the Central and Regional Arecanut Research Stations spread over in the states of Karnataka, Kerala, West Bengal and Assam had shown that elephant foot yam, banana and pine apple were best suited and most economical for growing as intercrops in arecanut gardens. Bhat and Khadei (1970) reported that successful intercrops for arecanut gardens include banana, pineapple, black pepper, and cacao. The results obtained from the large number of experiments laid out in the CPCRI and elsewhere were published in a special number of *Arecanut and Spices Bulletin* Vol. 5, No. 3, (1973). The results are summarized below:

Bhat (1973) recommended banana, pine apple, elephant foot yam, arrow root and cacao as intercrops. According to Sadanandan (1973), growing intercrops (yam, ginger, and pine apple) produced no significant adverse effect on the yield of arecanut palms. Among the intercrops tried, at Peechi, (Central Kerala) yam was the most profitable followed by ginger and pine apple as regards dry matter production per unit area. Abraham (1973) reported the results of the trial at Palode in southern Kerala. According to him, all intercrops (pepper, tapioca, elephant foot yam, *Dioscorea*, and pineapple), except sweet potato, gave reasonable additional returns. Bhandary (1973), while reporting the results of a trial at Thirthahalli in the *malnad* area of Karnataka, stated that growing the intercrops, banana, pine apple, cardamom, pepper, and betel vine, did not pull down the yield of arecanuts. He further observed that betal vine and pepper were the most suitable intercrops for malnad areas. Nagaraj (1973), based on the results of the trial conducted at Hirehalli *maidan* of Karnataka, stated that there was no adverse effect of growing intercrops (betel vine, banana, tapioca, and pine apple) on the growth and initial performance of areca palms. Brahma (1973) observed that banana as an intercrop, plays an important role in raising the economy of areca growers of West Bengal. Roy (1973), reporting the results of the trial at Kahikuchi (Assam), stated that the growth and yield attributes of the arecanut crops did not show any significant variation due to intercropping. He observed that when guinea grass and ginger were grown as inter-crops, the areca crop recorded the highest weight of nuts per palm. However, maximum profit per hectare was obtained from plots with betel-vine as intercrop followed by pine apple.

An experiment to find out the effect of growing banana in arecanut gardens for different periods of time with different densities of banana has been laid out at Vittal in 1963 (Annual Report, CRARS, 1967; Annual Report, CPCRI, 1977). The arecanut palms were spaced 2.7m × 2.7m apart. The intercropping treatments consisted of: (1) no banana throughout the period of experiment (i.e., a monocrop of areca); (2) banana as intercrop throughout the period of experiment at full level (i.e., with a spacing of 2.7m × 2.7m), (3) banana at full level for first three years and no banana thereafter, (4) banana at full level for three years and at reduced level (i.e., with a spacing of 2.7m × 5.4m) for the rest of the period, (5) banana at full level for three years and at reduced

level for the next three years and no banana thereafter, (6) banana at full level for six years and no banana thereafter, (7) banana at full level for six years and at reduced level for the rest of the period, and (8) banana at full level for six years, reduced level for the next four years and no banana thereafter. A single cultivar of banana, *Poovan*, was used in all the treatments. The cumulative yield data of arecanuts for six years after the fifth year of plantation life showed no significant difference between the treatments. It was evident that growing banana as intercrop has no adverse effect on the performance of arecanut palms.

At Peechi, another experiment to study the performance of seven cultivars of banana, *Peyan*, *Karpuravally*, *Dwarf Cavendish*, *Red banana*, *Poovan*, *Kunnan*, and *Nendran*, was initiated in 1975 (Annual Report, CPCRI, 1976) to spot out the most suitable variety of banana for intercropping in areca gardens. The study is progressing.

In recent years, cacao has become very popular as a mixed crop in arecanut and coconut gardens. Experiments with cacao as mixed crop with arecanut are in progress at Vittal since 1964 and at Peechi and Palode since 1969 (Annual Report, CRARS, 1967; Annual Report, CPCRI, 1971). Based on the initial observations, Bhat and Leela (1968) reported that cacao was likely to go well with areca as a mixed crop considering the early bearing of cacao under the conditions prevailing in arecanut gardens. The arecanut palms in the garden were not also adversely affected as was evident from the normal growth and flowering of the palms. Bhat and Bavappa (1972) observed that under arecanut, cacao trees commenced to flower 14 months after planting, and the first crop of mature fruits was harvested 13 months later.

The mixed plantation of areca and cacao, planted in 1964 at Vittal has three treatments, viz., (1) arecanut and cacao (variety Criollo) at 50:50, (2) areca as pure crop, and (3) cacao along the borders of areca garden. The arecanut palms commenced to flower three years after planting in all the plots. Cacao had no adverse effect on the yield of acreanut. In fact, there might even be some beneficial effect of growing mixed crops of cacao as is indicated by the higher yield of areca from such mixed gardens. The cacao planted as a border crop has suffered due to sun scorch. Bhat and Bavappa (1972) observed that 81% of all roots and 55% of fine roots (by weight) of cacao were concentrated within 60 cm radius of the tree. In the case of arecanut, 79% of all roots and 72% of fine roots were concentrated within 60 cm radius of the palm. The depth of penetration of cacao roots was 1.5m and that of areca 1.8m. The maximum concentrations of roots was within the top 50 cm.

Another mixed cropping experiment is in progress since 1969 at Peechi under irrigated condition and Palode under rainfed condition using a $2\times2\times6\times2$ split plot design to compare two methods of alignment, two levels of manuring and six cross-combinations of cacao. At Peechi, during the first six years of observation, the quincunn method of planting cacao with arecanut was found to be better than alternate rows of cacao with areca. Similarly, the number of pods per tree was significantly higher at higher level of manuring with a mean of 20 pods per tree as against 16 pods per tree at lower level of manuring (Annual Report, CPCRI, 1976). At Palode, under rainfed condition the performance of cacao trees was poor.

Another field experiment, laid out in a $6\times2\times4$ confounded asymmetrical factorial design, is running at Vittal since 1970. It has six spacing combinations for the two crops and two levels of manuring under comparison (Annual Report, CRARS, 1971). The spacing combinations are: (1) areca spaced at 2.7×2.7m and cacao at 2.7×2.7m, (2) areca spaced at 2.7×2.7m and cacao at

2.7×5.4m, (3) areca spaced at 2.7×2.7m and cacao at 5.4×5.4m (4) areca and cacao spaced at 3.9×3.9m in the quincunx method, (5) areca and cacao spaced at 3.3×3.3m in the quincunx method, and (6) areca at 1.8×5.4m and cacao at 3.6×5.4m. The two manurial treatments are: (1) both areca and cacao fertilized at 100g N, 40 g P_2O_5 and 140 g K_2O per tree, and (2) areca at 100g N, 40g P_2O_5 and 140 g K_2O per tree and cacao at 200 g N, 80 g P_2O_5 and 280 g K_2O per tree. Both the areca palms and the cacao trees have not reached the stabilised bearing stage. During the sixth year after planting, the yield of cacao pods per tree was maximum under 5.4×5.4m spacing and minimum under 2.7×2.7m spacing. The yield (number of pods) per hectare was maximum under 3.3×3.3m spacing. The areca palms have commenced to yield fruits (Annual Report, CPCRI, 1977).

8. Harvesting stage. Harvesting fruits at immature stage is a practice in vogue in many parts of the country. The maturity at which the nut is harvested and the season of harvest affect the quality of the processed nut considerably. Trials conducted at Peechi showed that the proportion of *vellai choor*, which fetches higher price than other trade varieties like *choor kora*, was more than those harvested at higher maturity levels when the fruits were harvested at 6-months' maturity stage (Annual Report, CRARS, 1971). In another study, it was found that the quality and quantity of kernel (*chali*) processed out of fully/ripe fruits was much better than those fruits which were not fully ripe. The former gave 8.6% increase in weight of *chali* and fetched 72% more price than *chali* from less mature (ripe) fruits (Annual Report, CRARS, 1969)

IV OTHER STUDIES

1. Root System. The arecanut, a monocotyledonous palm, has a fibrous root system. Bavappa and Mathew (1960) studied the root system of arecanut seedlings in the nursery stage and recorded that the spacing of arecanut seedling in the nursery markedly influenced root production. Root growth was very poor in closely spaced seedlings. Bavappa and Murthy (1961) observed that the maximum root concentration in adult palms was found within the first 60-90 cm radius of the palm. Bhat and Leela (1969) observed that 61-67% of all roots and 51-56% of fine roots were concentrated within 50 cm radius of the palm and more than 80% of all roots were within 1.00-1.25m of the trunk. Some roots extended laterally beyond 1.75m distance. The maximum concentration of 66-79% of all roots and 72-76% of fine roots were within the top 50 cm of soil surface. The second layer of 51-100 cm contained 18-24% of all roots and 14-20% of fine roots. The maximum penetration of the roots was up to 2.6m depth The roots of close planted palms penetrated deeper than those planted wider apart. The quantity of roots (dry weight) per unit volume of soil within the feeding zone increased with increasing plant density, whereas the calculated gross quantity of roots produced per palm decreased with increasing density of planting.

In another study made by the author in a low lying garden with high water table, the lateral spread of roots was found up to 2.75m distance from the bole. The roots went down to only 1.40m depth thereby showing that the penetration and spread of roots in low lying areas with higher water table was less as compared to well drained deep soils.

V. CONCLUSION

Arecanut is grown on a variety of soil types and under different agro-climatic conditions. It is grown from the coastal sandy

loamy soils of the west coast of the country to the laterite soils of the sub-montane regions of Karnataka and Kerala States. It is grown in the alluvial soils of Assam and West Bengal. It tolerates temperatures from a minimum of 5°C to a maximum of 40°C. Arecanut is cultivated both in the low rainfall areas like that of the *maidan* part of Karnataka which receives about 100mm rainfall annually and heavy rainfall areas like that of the *malnad* tracts of Karnataka receiving more than 4000 mm rainfall annually. Arecanut is cultivated from sea coast up to an altitude of about 1200m above mean sea level. It is quite natural that the response of the crop to various management practices, cultural, irrigation and manurial, cannot be expected to be uniform from tract to tract under such diverse conditions. Yet, the results of the studies carried out thus far have helped to standardise the cultural and manurial schedules to a large extent.

The techniques of nursery practices evolved from the nursery trials can be utilised in almost all the arecanut growing tracts. The results of spacing trials conducted have suggested that in general a spacing of 2.7× 2.7m, or slightly closer, will be applicable to a majority of the arecanut growing areas. The irrigation experiments have suggested that an irrigation of 30 mm when the CPE is 30 mm is adequate in areas where long dry weather prevails during the summer months. Regarding the N, P, K nutrition of arecanut palm, the results of the various manurial trials suggest that a minimum of about 50-100g of N is required per palm per year. About 40g P_2O_5 seems to be adequate for the palm. Regarding K_2O, the response to K_2O is obtained from about 70g to 140g per palm per year. The inter and mixed cropping experiments carried out at different centres have suggested a variety of crops that can go well with arecanut.

There are still many problems which require the attention of agronomists. Information on drainage requirements of arecanut gardens, the effect of water stagnation and fluctuations of subsoil water require to be studied. Management practices under rainfed condition and efficient use of water by various methods like trickle or drip irrigation are problems to be looked into. Since arecanut gardens are irrigated, weeds pose a serious problem. The effective tillage systems which would eradicate weeds and conserve moisture and nutrients are to be worked out. Application of large quantities of green leaf transported from distant forest lands is a common practice in the *malnad* of Karnataka. How well can this practice be replaced by growing cover crops in areca gardens is a problem not fully worked out. Another aspect of study is to know the rationale of application of fresh earth to areca gardens (as is again practised in the *malnad* of Karnataka). Practically, very little is known about the micronutrient needs of arecanut palm. Further, in the context of the present emphasis on inter and mixed cropping. the efficient or improved use of land, water, light and air has to be determined in a different way than when a sole crop of arecanut is grown.

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