Plant Community Interactions in Crop Combinations with Coconuts

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The effects of growing different species of crops in close proximity with coconuts are examined based on the experience and limited experimental results on scientific crop combinations with coconuts in India. Plant community interactions in intensive crop combinations with perennials are of greater magnitude and different nature than in the case of sole crops. Interactions between neighbouring plants with respect to growth factors are often described as forms of competition – for the growth factors absorbed through both leaves (light and CO_2) and roots (water, nutrients and oxygen). Apart from competition, interaction between components of the multispecies crop combinations may also result in sharing of growth factors and cause changes in the physical and biological variables in the ecosystem. Favourable ecoclimate, increased activity of beneficial rhizosphere micro-organisms and better efficiency in the use of native and applied nutrients are manifestations of such complementary interactions. Other interaction effects involving annidation, allelopathy, plant parasites, land equivalent ratio and economic complementarity are also considered.

Present knowledge on plant community interactions in perennials is too meagre; research has to be intensified on various aspects because research information available on the crop management of sole crop systems may not be applicable to the management of crop combinations. A few aspects which deserve immediate attention are indicated. The factors to be considered in such studies are so many that the conventional experimental techniques may be of only limited applicability.

Even though combination culture of tree crops like coconut is an age-old practice, intensification of cropping based on the modern concepts of multiple cropping in order to increase the productivity of the areas planted with such crops is one of the most recent and practically-oriented scientific initiatives concerning these crops in India. The underlying principle is one of 'ecodevelopment', which aims at maximum utilisation of resources through rational choice and management of crops that can be successfully grown under or between these perennials. Thus, various crop combinations have been developed and recommended for intensifying land use in areas planted with coconuts (Nelliat, Bavappa & Nair, 1974; Nair, Bavappa & Nelliat, 1975a; Nair & Varghese, 1976; Nair, 1977). The first step in this direction involved determination of the positive and negative results of growing other crops with coconuts, in order to find out the crops suitable for combination culture. As the next step, research has to aim at understanding the reasons for the observed behaviour so that the new practices could be based on sound principles. The effects of growing plants in close proximity, *i.e.*, plant

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community interactions, will be examined briefly in this paper based on the experience of crop combination studies with coconuts and the available experimental results.

COMPETITIVE INTERACTIONS

Plant interactions have been referred to as 'interference effects' (Harper, 1961) or 'neighbour effects' (Trenbath & Harper, 1973). But, normally in a plant community, interference between plants lowers absorption/interception rates of growth factors relative to those in isolated plants, and competition for these factors and possibly for others will begin. Therefore, interaction between neighbouring plants with respect to growth factors is often described as a form of 'competition'. Competition can be for such of the factors for which there is a pool of materials to draw their supplies, and it is initiated when the immediate supply of a single necessary factor falls below the combined demands of the plants (Donald, 1963). In a plant community, if the component plants are of similar nature as in a sole crop, and when the pool of resources from which they have to draw is of limited volume, then the successful competitor is the plant which draws most rapidly from the pool or which can continue to withdraw from the pool when it is at a low ebb. In crop combinations with coconuts, where the canopies of components occupy different vertical layers, the coconut palm is not subjected to competition for factors which are absorbed through leaves (light and CO_2). But they could be subjected to competition for factors absorbed by roots (water, nutrients, and oxygen). On the other hand, the other crops grown with coconuts could be subjected to short supply of one or all of these factors.

Competition for light

In general, plants have been classified into sun and shade species on the basis of light saturation curves, light compensation points, and depending upon their adaptability to selected light intensity (Boardman, 1977). When crops with a high demand for light are grown as lower storey crops in polyculture with tree crops, the growth rates and photosynthesis of canopies of the former are nearly proportional to the radiation which they intercept. Less solar radiation reaching such crops may make their growth increasingly difficult (Allen, Sinclair & Lemon, 1976). Artificial shade of 40–50% reduced sunlight caused a yield reduction of 30%, compared to that of full sunlight, for soyabeans (Catedral & Lantican, 1977) and 70% for mung beans, *Vigna radiata* (Lantican & Catedral, 1977). Trials at the Central Plantation Crops Research Institute (CPCRI), Kasaragod, India, have also shown that pulses grown as intercrops in coconut gardens were not successful (Central Plantation Crops Research Institute, 1976, 1977).

The distribution of light at different positions in the canopy zones of the tree crops varies very much depending upon their canopy pattern. The intensity of light at various positions of the plantation floor of a pure stand of adult coconuts at normal spacing (7.5 m x 7.5 m) during different parts of the year, as reported by Nair & Balakrishnan (1976), is given in *Table 1.* Such differences profoundly affect the growth and yield of intercrops growing at different positions of the interspaces. Considering a unit interspace of 7.5 m x 7.5 m square with four coconut palms at the four corners and the yield of individual intercrop at different positions of this interspace, the yield of a plant near the periphery of the area at 2 m distance from the palm will, usually, be only about 60% of that of the plant at the centre of this area. However, such differences in the growth of the intercrop cannot be related solely to the light intensity at the plantation floor.

TABLE 1. INTENSITY OF LIGHT (LUX) FALLING ON THE GROUND AT DIFFERENT POSITIONS OF THE CANOPY ZONE OF COCONUTS IN A PURE STAND OF 25-YEAR-OLD PALMS DURING THE PEAK BRIGHT HOURS OF THE DAY (NAIR & BALAKRISHNAN, 1976)

Distance from palm (m)	*Hour of measurements*				*Mean*
	10.00	*12.00*	*14.00*	*16.00*	
	March 1974				
1.00	8 500	9 210	9 240	5 700	8 162
1.75	14 220	12 715	12 228	6 320	11 370
3.75	11 860	30 000	30 000	7 780	19 910
	July 1974				
1.00	3 208	2 604	2 700	432	2 236
1.75	9 612	6 802	5 234	1 378	5 756
3.75	14 727	11 629	15 539	2 250	11 036
	October 1974				
1.00	4 658	2 818	6 528	1 218	3 805
1.75	6 234	4 860	6 846	890	4 707
3.75	7 893	12 500	7 600	2 907	7 725
	January 1975				
1.00	4 716	3 826	10 820	1 054	5 104
1.75	8 275	6 468	9 320	2 210	6 568
3.75	12 883	18 155	7 539	3 828	10 601

The spectral qualities of radiation will also change with depth of penetration into plant canopies because leaves absorb solar radiation differently (Allen *et al.,* 1976). About half of the energy in the solar spectrum falls in wavelengths greater than 700 nm, and is referred to as photosynthetically active radiation (PAR); the other half lies at wavelengths greater than 700 nm, and is referred to as near infrared radiation (NIR). Leaf pigments absorb more strongly in the PAR spectrum than in the NIR spectrum, and this differential absorption causes shifts in the average spectral qualities of radiation with depth into plant canopy. NIR/PAR ratio is roughly comparable to the 730 nm/660 nm ratio (Allen, Stewart & Lemon, 1974; Sinclair & Lemon, 1973, 1974). The relative enrichment of 730 nm/660 nm radiation will be greater in the lower canopy than in the upper canopy and will be much greater near sunset than mid-day. Therefore, the radiation received by the lower storey crops (*e.g.*, pineapple in a multi-storeyed crop combination with coconuts) will be having high NIR/PAR ratio, whereas the overstorey crop of coconut is not affected. This type of phytochrome mediated effect may be greater for intercrops in north-south rows than in east-west rows, because less radiation may be received near sunset between rows in a north-south system by shorter plants.

Plants grown in shaded conditions will try to adjust themselves to low light levels by various mechanisms such as reduced rate of dark respiration, lowered root/shoot ratio and greater leaf area/leaf weight ratio (Trenbath, 1976). These changes increase the competitive ability of the intercrops by increasing interception of light and reducing respiratory load. The shaded plants have a tendency to elongate their stems more rapidly than unshaded plants. However, if shading is too intense, extension of stem is reduced. This phenomenon can be observed in the growth of intercrops such as tapioca grown under the shade of young coconuts where the overstorey canopy, apart from being too intense, is of low height also. This indicates the importance of assessing the magnitude and nature of shade at the plantation floor before initiating crop combinations. Research has to be extended to such aspects of radiation interception and mechanisms governing adaptive changes to low light intensity, so as to perfect the crop combinations.

Although competition for CO_2 between components of a plant community is theoretically possible, so far it has been demonstrated mostly within sealed enclosures (Trenbath, 1976). The CO_2 environment does not change enough at the base of dense plant canopies to affect CO_2 uptake, because PAR rather than CO_2 limits photosynthesis at the bottom of the canopies. Respiration in the soil or by the lower canopy vegetation raises the CO_2 concentration only slightly in open crops such as tree crops (Allen & Lemon, 1976).

Competition for factors absorbed through roots

Water, nutrients, and oxygen are the growth factors taken up from the soil by roots. The uptake of dissolved nutrients or oxygen by a root surface establishes a concentration gradient, down which further supplies of the substance diffuse towards the roots (Dunham & Nye, 1974). Similarly, water uptake produces a gradient of water content, down which water flows in the same direction. This movement of nutrients, oxygen, and water to the root depletes the soil of these factors in the vicinity of the root. More mobile nitrate ions and water are usually taken up at faster rates than less mobile potassium and phosphate. Competition for soil factors among different components of a crop community begins when the depletion zones around individual root systems overlap, although competition among individual roots of the same plant may begin earlier. In many situations, the density of active absorbing roots is such that the depletion around adjacent roots overlap and there is a significant decline in the average concentration of solute throughout the zone exploited by roots (Nye, Brewster & Bhat, 1975; Nye & Tinker, 1977). The distance of the depletion zone depends on a variety of factors. The depletion zone for water and mobile ions like nitrates which are carried passively in moving soil water extends to much longer distance than for nutrients like phosphates and adsorbed cations (NH_4, K, Ca, Mg) which are at low concentrations in soil water and therefore move almost exclusively by slow diffusion (Brewster & Tinker, 1970). This narrowness of depletion zones for non-mobile nutrients tends to prevent competition for these nutrients between root systems of different crops in a crop combination, except at high root density. The knowledge of the rooting patterns of different crops in a crop combination, thus, becomes important.

COMPLEMENTARY INTERACTIONS

The interaction between neighbouring plants need not always produce a 'competition' for something, *i.e.*, for growth factors; it is also possible that the plants may complement each other in sharing growth factors and result in better utilisation of factors.

Biological complementarity

Based on the net effect of interactions between two species, Hart (1974) modified Odum's (1971) classification of interactions into:

(1) Commensalistic polyculture (no observable effect on one species and positive effect on the other),

(2) Amensalistic polyculture (no observable effect on one species and negative effect on the other),

(3) Monopolistic polyculture (positive effect on one species and negative effect on the other), and

(4) Inhibitory polyculture (negative net effects on both the species).

To these could be added a 'synergistic' polyculture where the net effect of interaction is positive on both species. The beneficial interactive effects of the crop combination of coconut and cocoa at CPCRI (Nair, Varma, Nelliat & Bavappa, 1975b) could be classified as commensalistic or synergistic where the crop combination not only reduces the influence of the yield depressive factors (*e.g.*, weeds) but also causes better efficiency in the utilisation of growth factors. This sort of complementary sharing of growth factors by the components of a crop combination has also been referred to as an example of 'non-monetary input' in crop production (Nair *et al.*, 1975b).

Ecoclimate

A crop combination can bring about alteration in the local climatic environment (ecoclimate) of the ecosystem. Nair & Balakrishnan (1977) compared the daily variations in climatic factors inside plantations of unirrigated and irrigated monocrops of coconut and that of a crop combination of coconut + cocoa, and found that the ecoclimate of the crop combination was different from that of a monocrop of coconut. The most striking difference was observed in daily evaporation, which was only about 30% and 60% of that from the open area under the crop combination and irrigated coconut, respectively. Values of evaporation (mm/day) from the different ecoclimates, expressed as percentage of evaporation from open area, are presented in *Table 2.*

Such phenomena of similar magnitude are likely to occur at other agro-ecological conditions also where crop combinations are practised.

Under tropical conditions, pure stands of 'open' crops (having long stems with little or no branching and limited number of long and flexible leaves at the tip of the stem, *e.g.*, coconut) permit better air movement within the stand. In such cases, the air temperature above the floor during the hot hours of the day will be a few degrees less than that at the ground surface (Nair, 1978). This causes movement of air from the heated soil surface to upper layers by convection. Presence of more crop cover on the plantation floor causes a reduction in air movement within the crops and of temperature near the floor, and thus decreases the possibility for air movement by convection. This could be one of the reasons for the reduced evaporation within the crop combination (*Table 2*). Moreover, because of the crop canopies, the crop combination is less ventilated and offers greater aerodynamic roughness. Thus, the crop combination acts as a buffer against drastic changes in ecoclimate. This will have considerable effect on the various biological processes occurring in the environment (including soil) of the crop community.

TABLE 2. EVAPORATION FROM DIFFERENT ECOCLIMATES EXPRESSED AS PERCENTAGES OF EVAPORATION FROM OPEN AREA (NAIR & BALAKRISHNAN, 1977).

Month	*Ecoclimates of*			
	1	*2*	*3*	*4*
		1974–75		
November	100 (7.4)	75.7	66.2	36.5
December	100 (6.2)	75.8	69.4	30.6
January	100 (5.8)	79.3	62.1	27.6
February	100 (5.3)	83.0	56.6	24.5
March	100 (5.0)	102.0	76.0	32.0
April	100 (6.1)	86.9	68.8	30.6
May	100 (5.8)	84.5	58.6	29.3
Mean	100	80.9	65.4	30.1
		1975–76		
November	100 (5.7)	68.4	52.6	29.8
December	100 (5.9)	71.2	61.0	30.5
January	100 (6.2)	64.5	51.6	27.4
February	100 (6.3)	68.3	47.6	25.4
March	100 (6.3)	69.8	44.4	22.2
April	100 (6.3)	82.4	52.7	25.7
May	100 (7.4)	91.9	68.9	28.4
Mean	100	73.8	54.1	27.0

Figures within brackets are the mean monthly values of evaporation (mm/day) from the open area.

1. Open area
2. Unirrigated coconut
3. Irrigated coconut
4. Coconut + cocoa combination

Soil microorganisms

The nature of microorganisms associated with perennials such as tree crops is likely to be almost constant, but the introduction of other perennials could change this equilibrium either beneficially or detrimentally for the crop community. In one of the first studies of its kind, Nair & Rao (1977) found that there was intense microbial activity in the rhizosphere of coconut with which cocoa was planted as a mixed crop. Increased volume of dead roots additional organic matter formed during active root growth, and the fallen leaves from crops like cocoa provide the organic substrate for the growth of such microorganisms. The activity of the rhizosphere and root surface microorganisms can also affect nutrient uptake by plants (Bowen & Rovira, 1969).

Interaction between plants involving production of biologically active plant exudates is known as allelopathy (Grümmer, 1955; Trenbath, 1974). A wide range of organic compounds are already known to be present in the rhizosphere (Rovira, 1965; 1969). If one of the genotypes liberates specific autotoxins or substances which stimulate others, the effect on growth of crop community in total is likely to be beneficial (Webb, Tracey & Haydock, 1967). In Australia, the presence of one species of *Eucalyptus* is said to double pasture production while other species are used in parks to suppress grass growth. In both cases, allelopathy has been invoked (Rice, 1974). Allelopathy is likely to occur in crop combinations with coconuts, but it is yet to be established.

PLANT INTERACTIONS AND FERTILISER MANAGEMENT

The three important practical considerations in fertiliser management in the context of polyculture are ensuring adequate supply of nutrients to the individual species, avoiding indiscriminate use of fertilisers for any one species and ensuring economy in the use of native and applied nutrients by making best use of plant interactions. Usually, the yield depressions caused by an added second crop are greater when soil fertility is low than when it is high (Stanford, Legg & Smith, 1973). This is possibly the situation that results in yield reductions of coconut and the intercrop when the intercrop is not manured (Central Plantation Crops Research Institute, 1971).

The importance of crop combinations in the context of nutrient economy has been indicated in the system analysis studies by Khanna & Nair (1977). A fraction of the nutrients, particularly K, taken up by the plant is washed out of the leaves through rain water. Presence of this fraction, which is circulated within the ecosystem is a sort of 'necessary evil' and indicates the minimum amount of losses of K which has to be reckoned with while calculating the total uptake of K. Khanna & Nair (1977) surmised that the presence of more plant cover as in a crop combination system increases the plant cycling fraction of nutrients and thereby reduces the 'direct loss' of nutrients in percolating water. Moreover, more root volume of the crop combination can cause the formation of more organic matter during active root growth directly from the root tissue (Martin, 1977; Sauerbeck & Johnen, 1977). The observation of Nair & Varghese (*unpublished*) that the organic carbon content was higher (0.64% in the 0–30 cm soil and 0.37% in the 30–60 cm soil) in the root zone of coconut palms than at the centre of four palms (0.46% in 0–30 cm and 0.29% in 30–60 cm depths of soil) is a result of this process. The steady release of carbohydrate-rich organic matter from actively growing roots represents energy input into the soil ecosystem, and it can support a substantial microbial population. This phenomenon is very important in nutrient cycling in perennial cultures.

Land equivalent ratio (LER)

The concept of land equivalent ratio (LER) has been proposed (International Rice Research Institute, 1974, 1975) to help judge the relative performance of the component of a crop combination compared to sole crops of that species. If the yield Yi of the i-th component from a unit area of intercrop is expressed as a fraction of the yield Yii of that species grown as a sole crop over the same area, the LER of the intercrop is given as a sum of the fractions:

$$\text{LER} = \sum_{i=1}^{m} \frac{Yi}{Yii}$$

where m is the total number of species involved. When LER is unity, the various yields from the crop combination could have been obtained from the unit area planted to sole crops, each occupying an appropriate fraction of the total area, and the overall yield per unit area of crop combination does not exceed that of the most productive sole crop. In order to justify a polyculture, its LER has to be 1 + x, where the additional yield of the crop combination over that of the sole crops will be 100 x %.

LER measurements have not been done for crop combinations with coconuts. But, it can be surmised that when the yield of coconuts is not adversely affected, crop combination will result in LER of 1 + x, where x corresponds to the extra yield obtained from additional crop. This would mean that extra x unit of land would have been necessary to produce yield which contributed to the increase in LER over unity by x. The optimum density of the additional crop to get maximum value of x can be calculated. Based on the experience and experimental evidence available so far, Nair (1978) has projected the different possibilities as in *Figure 1.* Three sets of conditions are visualised: (1) no effect on the yield of coconuts by intensive cropping; (2) coconut yield is adversely affected; and, (3) coconut yield is beneficially affected. Under each of these conditions, the yield of additional crop per unit area may (a) increase with increase in its planting density, (b) increase up to a certain level and then remain constant, or, (c) increase up to a certain level and then decrease. The assumption here, though it may not be valid always, is that the relative yield of an additional crop at its optimum density does not exceed 80% of its yield when grown as sole crop under optimum conditions.

Annidation

Complementary use of resources by exploiting the environmental

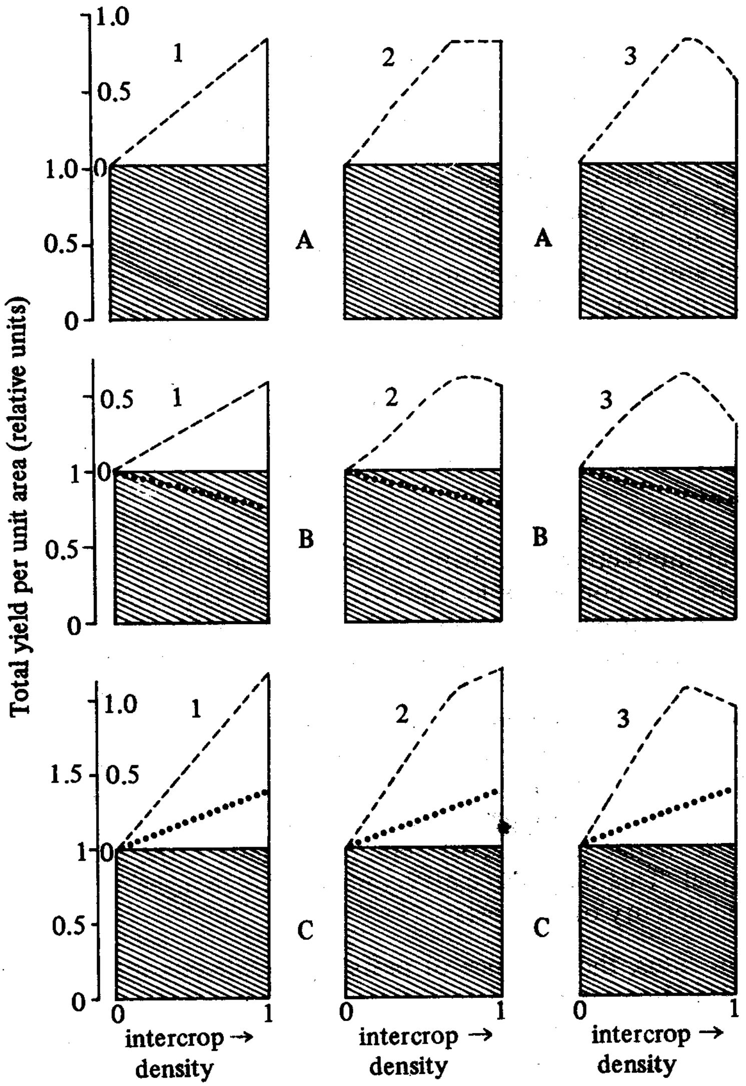

Figure 1. Models showing the effect of crop combinations on the total productivity per unit area.

Note:

(Yields of crops are shown in relative units as compared to yield of the same species in sole crops)

The shaded area represents the yield of coconuts had there been no additional crop.

Broken lines (- - - -) denote the yield of additional crop and dotted lines (. . . . .) that of coconut as influenced by the crop combination.

A, B, and C are the three situations of the effect of crop combination on the yield of coconuts, and 1, 2, and 3 are of the yield of additional crop with increasing plant density.

(Nair, 1978)

supplies in differing ways by the components of a community has been termed annidation (Ludwig, 1950). When canopies of a multispecies plant community (*e.g.*, multi-storeyed crop combinations with coconuts) occupy different vertical layers with the tallest component having foliage tolerant of strong light and high evaporative demand, and the shorter component(s) having foliage tolerant of shade and/or relatively high humidity, it involves annidation in space. Plant species making different demands on the nutrient pool of a site is an example of annidation with respect to nutrients. Examples of annidation in time are also possible when a crop is relay planted among the maturing plants of the preceding one. The extent of yield depression caused by the preceding crop on the relay planted crop and *vice versa* have to be assessed to measure the variation in LER caused by this practice.

Plant parasites

Biological interactions involving microorganisms, insect pests, and plant pathogens are of considerable importance in crop combinations. The significance of rhizosphere and root surface microorganisms has already been briefly considered earlier. In order to consider the insect pests and other pathogens together, the term 'pest' shall be used here in the broad ecological context to denote those organisms dealt with in weed science, entomology, plant pathology, and zoology which have surpassed man's tolerance levels in the exploitation of temporary habitats (agroecosystems) created by him to cultivate his crops. Introducing additional crops in existing perennial crops brings about a change in the ecosystem, particularly if the additional crop is also a perennial. This may also cause concomitant changes in the population dynamics and activity of the pests.

In certain cases, the presence of pests can result possibly in better yield in crop combination compared to the combined yield of the components in sole crops. If one component (A) in a crop combination is attacked by a pathogen, its plants compete less effectively for resources. The increased uptake of growth factors by plants of the unattacked component (B) may produce enhanced growth, compensating for the yield reduction of A plants (Bardner & Lofty, 1971). Moreover, additional crops in a crop combination with reduced plant density as compared to the sole crop of that species may be less susceptible to the attack of host-specific pests owing to less land area to host crop and reduced host exposure. Thus, crop diversity in close proximity may lead to crop protection as suggested by Litsinger & Moody (1976). But the problem could be very serious if all components of a mixture are susceptible to a common pest; for example, the fungus *Phytophthora palmivora* can attack all the crops in a crop combination of coconut + black pepper + cocoa.

Nematicidal properties have been reported for plants like marigold (*Tagetes* sp.) which keep the nematodes (*Pratylenchus, Tylenchorhynchus,* *Rotylenchulus,* and *Meliodogyne*) under check (Wallace, 1963) and *Crotolaria,* which, though susceptible to the burrowing nematode, *Radopholus,* traps the nematodes inside the roots where they remain throughout their lives (Birchfield & Bistline, 1956; Agricultural Board, 1968). Although a number of crops grown with coconuts have been screened for their relative susceptibility to the nematodes (Central Plantation Crops Research Institute, 1976, 1977), studies aiming at the control of the nematode population by suitable crop (plant) combination do not seem to have been undertaken.

Economic complementarity

The relative allocation of inputs among the components of a crop combination has to be based not only on the profitability in producing one product, but also on the profitability of competing uses of that input in other products (Hildebrand, 1976). While considering increasing investments of an input to be used for two (or more) crops, the amounts allocated to each crop should be such that the marginal value product of the input (*i.e.,* the value added to production by the last unit of input) is equal in each subsequent use of the input to each of the component crops. This would mean that if a crop (or a variety) responds more to the application of an input, say fertiliser, it should be fertilised in preference to another crop which is known to be less responsive to fertiliser. Similarly, among the inputs, the one which gives better returns has to be preferred over the increased use of others. For example, if irrigating coconuts is more profitable than increasing the amounts of fertilisers, the resources have to be preferentially used for irrigation. This sort of judicious choice of inputs and their allocation to the component crops helps us to get the best out of the available resources. It will, then, result in economic complementary interaction mentioned earlier.

Plant community interactions in mixed stands are too many to be sorted out, or even to be studied experimentally. The variables in an experiment have to be limited in number, and any amount of conventional experiments to study the response of plants to a limited set of artificial conditions will not reveal the many aspects of plant interactions. In order to consider all the factors simultaneously and to integrate available knowledge on various aspects, the principles of system analysis and ecosystem modelling could be made use of. The methodology and advantages of system analysis approach to nutritional studies on coconut-based ecosystems have been suggested by Nair (1978).

CONCLUSION

Apart from narrating the trivial artefacts of positive and negative results of growing two or more crops together, research on crop combination with perennials should aim at identifying the promising observations and understanding the reasons for the observed behaviour. This will lead to exploitation of the favourable effects as well as the avoidance of the unfavourable ones of growing crops in close proximity. Research information available on crop management practices for sole crops may not be applicable as such for the management of crop combinations. The objective should be to maximise the profitability of the whole system, with limited resources, rather than the individual crop's yields. Introducing new crop species, replacing varieties, and arranging crops in time and space will result in substantial changes in the physical and biological variables in the agroecosystem. But, there is a considerable gap in our present knowledge on the effects of these interactions of plant species; what happens below as well as above the ground in sharing of growth factors and other resources when plants are grown together has to be investigated in more detail. Radiation interception and changes in the spectral qualities of radiation with depth of penetration of radiation into plant canopies, rooting patterns and overlapping of active root zones, rhizodeposition of organic matter by living roots, recycling of nutrients in the ecosystem through canopy washout, magnitude of loss of nutrients in percolating water, beneficial effects of interactions involving microorganisms, pests and pathogens, etc. are some of the areas in which research has to be intensified. Comprehensive studies on all these parameters may not be feasible, but at least an intuitive information on the interactive effects is essential. In order to intensify research and consider all the interacting factors simultaneously, the principles of systems analysis can be made use of.

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