PHYSIOLOGICAL ASPECTS OF INTERCROPPING

by

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INTRODUCTION

For centuries, primitive man depended exclusively on hunting and gathering for his food and shelter. With the invention of agriculture, involving the domestication of animals and the ennoblement of plants, man has increasingly depended on farm-grown food, and much less on food from the wild, for his survival. The advances in chemistry, plant nutrition and introduction of rotations in the 18th century, and later applications of science and technology, revolutionized agriculture in temperate countries. Production and returns from farming were maximized by replacing human and animal power by techniques requiring fuel and other forms of energy, chemicals and better managerial ability. Heichel (1973) has concluded that, while this development maximized production of digestible nutrients, it decreased caloric gain from 15-5 because the supplemental energy involved was utilized less efficiently.

Modernization of agriculture in temperate countries involved genetic manipulation of crops and animals, development of better soil management techniques, rotation of crops, environmental manipulation and socio-economic developments which maximized agricultural production. A general practice in this development related to the concern of this workshop is the widespread use of monoculture and row crops of uniform genetic characteristics. It is with reference to this modern cropping system that Milthorpe and Mosby (1974) defined a crop as 'an aggregation of individual plants, usually of the same species and normally of similar genetic constitution grown in a particular location for a specific product required by man'.

More recently the so-called "Green Revolution" in certain parts of the world, such as South East Asia and Mexico, brought tremendous food production gains and raised false hopes that the solution of the less developed countries' food problems in answer to the population explosion was just around the corner. According to Smith (1971) this revolution involved the evolution of an entire agricultural matrix usually equated with the introduction of new high yielding varieties. This included a shift towards vast acreages of not just a single crop plant but a single crop variety highly selected for its yield rather than for a range of other desirable characteristics; new management practices (such as fertilization and irrigation) which enhance high yields, but sometimes increase crop disposition to diseases and pests; large scale use of pesticides, and infrastructural development for the timely supply of inputs, credit, storage, and marketing facilities.

Those techniques were first extended to favourable physical environments and later to borderline areas where physical investments have transformed them to higher potential (Harwood, 1974). Thus the Green Revolution is as much cash and power based and specialized as the agriculture of highly developed temperate countries.

In large areas of the world, especially in the humid tropics, agriculture has emerged from a relatively primitive stage to a transition agriculture still relying heavily on human and, to a less extent, animal power. While the farm house and the compound farm are sedentary, the prevalent cropping systems outside the compound farms involve cycles of cropping for two or three years followed by varying periods of fallow during which fertility is restored by natural recycling of nutrients rather than with fertilizers. A slash and burn bush clearing practice with heavy manual labour requirements prepares the ground for a mixed or intercropping system. Heichel (1973) estimated that, in this type of agriculture in New Guinea or the rice culture in the Philippines, digestible energy yield is small but the caloric gain of the cropping system is large with about 16 calories of digestible energy harvested for each calory of cultural energy invested. Very complex crop mixtures often involving tree crops, staple food crops, vegetables and other useful plants are widely grown as compared to the relatively simple modern mono-cropping systems in Europe and North America. Here agriculture emphasizes diversity of production and activities which satisfy the needs of the farm and the family rather than specialization on a single product grown for sale in order to make cash available for the purchase of goods and services. This paper reviews the characteristics of intercropping, its advantages and why it is recently attracting much attention in addition to a brief consideration of the physiological problems that may be associated with it.

INTERCROPPING, ITS CHARACTERISTICS, ADVANTAGES AND PRESENT INTEREST IN IT FOR THE HUMID TROPICS

Apart from the monoculture of plantations, cash and export crops, which are of course not much widespread in the humid tropics of Agrica, mixed cropping or intercropping is the general practice. In most cases small numbers of livestock are also involved. Farmers, who live in the rural areas constitute over 70% of the population. Their farm enterprises are characterized by (1) small size, 0.1-2 hectares, (2) low income and lack of capital for purchase of necessary inputs, (3) heavy reliance on human labour, (4) shortage of labour at periods of peak farm activities, (5) farming activities related to the rainfall regime with rainfall unevenly distributed and varying seasonally from excess to too small, (6) soils highly weathered and of low fertility and (7) diversity of farm enterprises including non-farm activities, trading and various home industries. The needs of these farmers who used to be mainly subsistence include (a) adequate supplies of staple foods which should preferably be regularly available in the fresh state because of lack of refrigeration and unsuitable environment for drying, (b) fuel for cooking, (c) materials for building, fiber and other structural materials and (d) availability of cash for purchase of goods and services and fulfilment of socio-cultural obligations such as taxes, fines, school fees, religious dues, etc. All these characteristics and needs are typical of those enumerated by Harwood (1974) for farmers of South East Asia. These farmers are unable to adopt improved crop production practices which rely on monoculture and widespread use of pesticides. They cannot afford materially to practise modern multiple cropping techniques such as those of Taiwan and Japan which are beyond their managerial ability and for which regular supply of inputs at the right time is impossible. They appear to have been overlooked by local research institutions and no attention has been paid to their needs (Harwood, 1974). Some of the improved practices applicable to their situations cannot get to them because of inadequate extension, lack of good roads, etc. As long as they will continue to be partially subsistent and partially commercial, mixed cropping on the small acreages available to them is more or less imperative. It assures them stability of production, minimization of risks and better nutrition. Mixed and intercropping systems should, therefore, be adequately studied, experimentally modernized, adapted to the conditions in which the rural people live and made economically viable and socially acceptable to them. Few serious studies have really been made of intercropping but the few that have been carried out and relevant observations indicate that it has the following advantages and disadvantages (Norman, 1968; Harwood, 1974; Okigbo, 1974):

1. It involves a built-in rotation in which compartible crops utilize nutrients at various levels and may symbiotically affect one another.

2. It constitutes an insurance against crop failure due to diseases, pests and other adverse environmental conditions (Norman, 1968).

3. Especially in the humid tropics, intercropping provides continuous cover of the soil throughout the year and protects the soil against erosion.

4. It supplies the farmer with a range of foodstuffs which are available at different times of the year, thus, ensuring that he has a more balanced diet while also reducing some storage problems.

5. Mixed cropping of the compound farm type includes plants that can be put to multiferous uses for shelter, staking materials, fibre, beverages, etc. thereby constituting some savings in labour or cash if he were forced to obtain them from elsewhere.

6. It constitutes a reserve of sometimes potentially useful sources of germplasm of plants with beneficial characteristics.

7. Mixtures of crop plants constitute efficient utilization of resources since they facilitate the use of both heliophytes and shade loving plants and the density of plant growth often reduces weed growth and cost of weed control. Some plants in the compound farm are of major cultural importance to the farmer since they are of social and religious importance.

8. A major disadvantage of mixed cropping is that it renders the use of certain inputs such as fertilizers, machinery and pesticides impossible or impractical. Very often, in compound farms where oil palm groves or permanent tree crop density is not controlled, non-shade loving arable crops either fail or perform very poorly even where adequate amounts of fertilizers are applied.

PHYSIOLOGICAL ASPECTS OF INTERCROPPING

The Role of the Crop Physiologist

All living things depend primarily on the products of photosynthesis for survival and development. Crop production systems involve various management decisions and activities whereby the genetics of crop plants and the environment are manipulated to enhance production of products useful to man. These include the number, timing, sequences and amounts of various inputs used in the production process. Each plant species or cultivar possesses characteristic morphological and physiological features which exhibit genetic and environmental variations. Changes in these features occur during the development of the plant and the features during each stage of development may vary according to circumstances.

According to Monsi et al. (1973), the morphological features as characterized by the geometrical structure or architecture of the plant canopies influence to a great extent the action and reaction between plants and their environment through the modification and interception of fluxes of radiation, heat, carbon dioxide, etc. Thus, canopy structure is regarded as the determinant of p photosynthetic activity and, consequently, crop productivity. Canopy structure and physiological properties of leaves in relation to the processes of photosynthesis and respiration affect the role of competition between plants. The plant canopy is part of a system consisting of a number of components: the size, numbers and nature of initial propagules, the function and growth of the plant during their developmental stages and the environment in which they occur (Milthorpe and Moorby, 1974). The environment of the plant is the zone of activity of various physical and chemical factors outside the plant which may be modified by size, numbers and arrangement of the constituent plants.

The crop physiologist is concerned with the study of details of the biochemical and physical processes involved in photosynthesis and other processes which occur in plants and interact with the environment to produce yields of various products. Thus, he studies canopy structure (the vertical and horizontal distribution and spatial orientation of leaf elements) and the micro-environmental factors such as radiation intensity, temperature, wind and carbon dioxide concentration which influence photosynthesis. He is also interested in the changes and conditions of the micro-environment within the plant canopy and the root zone in relation to the local climate within which the plant exists in addition to the rhythmic phenomena which affect various processes and morphology of plants. All these he does in order to explain the determinants of various components of yield as a basis for prediction of crop performance under specified or monitored environmental conditions. In this way, the crop physiologist could effectively provide feed back information to crop improvement scientists as to the structural and other relevant characteristics of model high yielding plants.

Intercropping

For simplicity in this paper, intercropping is defined as the practice of growing more than one species of crop plants on the same plot of land. The crop plants may be planted at the same or different times. Some of the component crops may be planted and harvested one, two or three times in the same season or year.

The complexity of the crop mixture may range from where there are only two species of either annual staples or perennial tree crops and weeds to where there are perennial tree crops, semi-perennial woody or herbacious shrubs such as castor beans or plantains, cassava which takes 9 to 18 months to harvest, yams and cucurbitaceous climbers for which other crops provide support, cocoyams and vegetables less than a metre in height to sweet potatoes and prostrate weeds just on the surface of the ground. This situation which is found in compound farms results in an agroecosystems which approximates a multistoreyed natural forest in its structure and probable ecological stability. The geometrical pattern of planting may vary some plants are in rows or strips, triangular and staggered spacings, intricate honey-comb patterns and others that may be designated as haphazard for lack of adequate geometrical description. The nature of the patterns and the varying distances involved affect crop canopies, wind speed, CO_2 concentration, etc. and, hence, competition among the various species.

The number of species involved may exceed 50 in half a hectare of land in traditional agriculture in the humid tropical areas of tropical Africa. Each species in the mixture whether its parts are in contact with others or whether the whole plant is in contact with the same or other species is influenced by competitive effects of other plants. Apart from structural differences characteristic of the species, there are morphological differences due to the positions occupied by individual crop stands. For example, plants of the same or different species which are of the same height may exhibit height differences when planted in different parts of a mound or a ridge and in various topographic situations with different depths of soil and varying distances above the water table.

Depending on the different times of planting, spacing, duration of the life cycles and other factors, the times they attain their maximum leaf area development may coincide, overlap slightly or vary tremendously. All these factors should be taken into account in the study of performance and yields of crops in mixtures which result from within plant, intraspecific and interspecific competition for space, light, carbon dioxide, water, nutrients, etc. These factors and conditions also produce different temperature and wind effects in addition to modifying the processes of photosynthesis, evapotranspitation and various rhythmic changes that plants undergo. The penetration of light within the canopy, relative humidity within the canopy and nature of plant species adjacent to each other would affect the incidence and intensity of damage due to diseases and pests. In intercropping experiments, the agronomist is interested in measuring yield, competition among plants, compatibility of the components of the mixture as may be reflected in quantitative terms such as weight of dry matter production and height of plants. Observations may be made on disease incidence, symbiotic relationships and toxicity effects of certain mixtures. But the elucidation of the nature of the factors contributing to these quantifiable characteristics belongs to the crop physiologist. So far, this has received very little attention because of the emphasis given to monocropping and the awe with which the complexity of mixtures in traditional agriculture are viewed by agronomists and physiologists who are more conversant with monoculture.

Various aspects of mixed cropping have been with us even in modern plantation agriculture. For example, Williams and Joseph (1970) cited the practice of intercropping fast growing annual crops which mature in weeks among widely spaced perennial tree crops which mature in years. Lim, quoted by Williams and Joseph (1970), listed conditions under which intercropping of annuals with perennials is most practicable such as that the intercrop should not retard the growth of the major crop and should not harbour pests or disease organisms. Large numbers of annuals are often planted with semi-perennial or short term crops such as mixtures of bananas, pineapples, maize, cassava, sweet potatoes and groundnuts.

Effects of intercropping in normal plantation practice have been studied (Williams and Joseph, 1970). In tea, heavy dressings of nitrogen in the shade have been reported to reduce yields but increase yields in sunlight. It is a regular practice to grow coffee and cocoa under shade but evidence has now accumulated that cocoa, for example, gives higher yield in full light but shade may be essential during establishment. At NIFOR (Benin) intercropping was reported to increase the growth rate of oil palms as a result of extra cultivation and water infiltration. While maize legume mixtures may result in higher nitrogen availability to the maize, the climbing legume may tightly bind the maize culms producing stresses which may reduce translocation and yield, hold leaves at various angles, decrease or increase shading of lower leaves and sometimes cause premature leaf drop. Enyi (1972) reported intercropping of maize and sorghum with cowpeas, pigeon peas or beans led to a reduction in leaf area indices, fresh weight yield at times of anthesis, straw yield at harvest and grain yield of cereals. We observed that although intercropping maize with either beans or cowpeas decreased total yield of grain (cereal and legume) per hectare it increased total grain yield in sorghum with pigeon peas. In traditional agriculture in the humid tropical areas of Nigeria, shade tolerant species such as cocoyams and marantaceous fibre crops are grown under tree crops while less shade tolerant species such as maize are grown under heavily pruned trees or in the open.

It is, therefore, necessary that for effective feedback to plant breeders and development of suitable selection criteria, plant physiological studies and relevant observations should be associated with intercropping experiments on (i) date of planting and pattern of planting, (ii) spacing and pattern of intercropping, (iii) fertilizer mixtures and placement in intercropping and (iv) strip cropping, relay and multiple cropping. Factors such as spacing and pattern of planting of various species of crop plants may affect wind, relative humidity, CO_2 concentration and light incidence and diffusion within the crop canopy in addition to water stress, air and soil temperatures, photoperiodic responses, and nutrient uptake in relation to growth and development of the crop and various phenological phenomena taking place during the various stages of development at different times of the year. Identification and selection of plant structures and other characteristics that can be used in developing suitable criteria for predicting crop performance in mixtures also require that plant physiological studies and related observations should be carried out simultaneously with intercropping.

The management of multispecific plant communities in intercropping as in range management should aim at maintaining or attaining balance among the different species involved ARS/USDA (1974). Plant physiologists could assist in determining the structures of and species of crop plants that could be compatibly grown together to produce reasonably stable and high yields in mixtures.

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