Concepts and Principles in Cropping Systems

Research and Testing

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Improved farming and Cropping system[1/] research has evolved from individual crop or input programs. Such an evolution (Fig. I) dicatates we much now pursue a more complex program that includes interrelationships among cropping systems which, if not taken into account my negate changes which experimentation on individual crops or inputs suggest. That such research and testing must be both multi-disciplinary and inter-institutional, directed at locate specific small farmer situations, is gradually being accepted.

Fig. I. Evolution of Food Crop Increase in Developing Countries Since World War II

in Broad Context

	10 year Periods.	Program Components	
World and	1945 - 1955	1) Increase Area Cultivated 2) Commercial fertilizer	Problem
Thai	1955 - 1965	1) New Varieties 2) Fertilizer Nitrogen	Complexity Increase
Population	1965 - 1975	1) Cropping Systems 2) "Packages" of Cultural Practices	Inter-Institutional and
x $2\frac{1}{2}$ increase	1975 - 1985	1) Farming Systems 2) Rural, Community Development	Multi-Discipline Need Increase

1/ Sequential cropping, intercropping variations and related terminology used in Multiple cropping and Farming systems : see Appendix I.

The purpose of this paper is to develop concepts and principles for improved cropping system research and testing with special reference to climatic, physical, biological Technical and time-space characteristics, though reference will also be made to appropriate socio-economic factors.

Five factors which suggest the basis for certain concepts and principles in effective Multiple Cropping research and testing are :

(1) Climatic and Physical

(2) Bilolgical and Technical

(3) Time and Spacial

(4) Social and Cultural

(5) Economic and Markets

Climatic and Physical :

Concept : From an agro-climatogical view-point the interaction of two climatic components such as precipitation and temperature provides important information that sets parameters for the kinds of cropping systems in dryland regions and crop improvement programs in the irrigated areas.

Principles :

(1) A Climatic chart (Appendix II) based on mean monthly temperature and precipitation indicates constraints for dryland cropping or specific crop performance under irrigated conditions. Thus in non-irrigated areas the feasibility of different double cropping patterns can be studied, while in irrigated regions, where three

and four cropping systems are possible, low temperature during December and January may suggest a comparative advantage for vegetable crops or wheat over soybeans or peanuts. Climate charts are a useful and simple tool to broadly define kinds of cropping patterns.

(2) Water balances provide a more useful guide in the relationship between climatic phenomena (precipitation, temperature, air humidity, wind radiation) and plants. Water balances, although based on theoretical measurements such as potential evaporation P.E. (Appendix III) give periods of moisture surplus and deficits that influence soil management practices.

(3) Land preparation, seeding, species and variety selections, date and rate of fertilizer application in cropping systems can be determined from water balance information.

(4) When open pan potential evaporation data is compared with actual field consumptive use measurements, practical correlations can be established for a given crop under defined conditions which make extrapolation of water use requirements to other situations possible. However both seasonal and annual rainfall variation averages used in water balance and climatic records can be misleading (Appendix IV). In Chiang Mai the wettest year received 1563 mm and the driest only 1057 mm between 1971 and 1976

(5) Without irrigation it is imperative when planning cropping systems to consider not averages but dependable precipitation. Dependable precipitation is defined as rainfall of a specified minimum probability of occurance. A 75 % probability is generally accepted as a reasonable risk value for agricultural decision purposes. The Farming Systems Research Program[2] at I.C.R.I.S.A.T. has suggested land preparation sowing dates, suitable crops and cropping patterns using the 75 % rainfall probability approach combined with the characterization of soil moisture storage. A farming operation calender is shown in table 1.

Table 1. Suggested Calender for seed-bed preparation and Sowing for non-irrigated Monsoon Crop Season based on dependable rain.

Farming Operation	Soil Type: Deep Silty Clay	Soil Type: Shallow Silty Clay	Soil Type: Shallow Loams
1. Preparatary Tillage	Before June 18	June 4-25	June 11-25
2. Seed-bed Prepartion	" "	Before July 2	Before July 2
3. Sowing (Drought Tolerant) a) b)	June 18	After July 2	After July 2
Sowing (Drough Sensitive)	June 25	" "	" "

a) millet, setaria etc. b) Corn, Sorghun etc.

2/ Annual Report 1975-76. B.A. Krantz et al

Note : The concept suggested by this example and the example which follows is that sound cropping systems and management decisions can be based on selected climatological and soil moisture information.

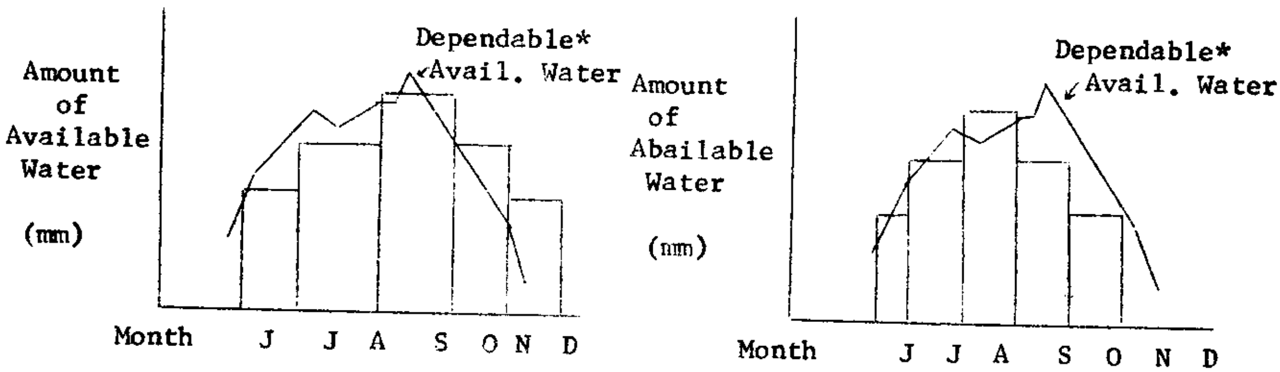
(6) Probabilities of crop available water over the growing season can be determined from information derived from three parameters:

1. Weekly rainfall
2. Potential evapo-transpiration and
3. Available soil moisture

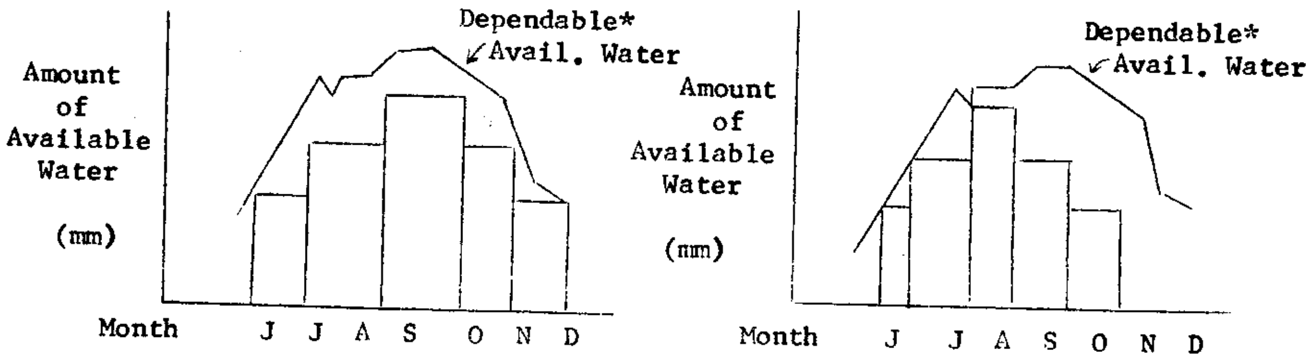
Independently, actual plant or system water requirements during the entire growing season can be obtained. With plant water requirements and 75 % dependable moisture (including soil moisture) established, selection of cropping systems for a specific location may be achieved. This may be seen in Figure II (adapted from ICRISAT data), where water requirements for long and short day plants are indicated in bar graphs. Dependable moisture, (an integrated index or rain, evapo-transpiration and available soil moisture) is superimposed over the bars as a solid line graph.

Fig. II. Fitting Long and Short Duration Crops with varying water requirements on two different Soils. (Adapted from ICRISAT, INDIA Data 1976)

Long Duration Crop (s) | Short Duration Crop (s)



SOIL (A) with 150 mm Available Water



SOIL (B) with 300 mm Available Water

*Note : (1) Dependable available water graph is an integrated index of rainfall, soil and evapotranspiration

(2) Bar graphs represent actual plant water needs

The graph shows (Fig. II) that both long and short day plants are subject to moisture stress when grown on the soil with 150 mm of available moisture. However, stress occurs at different periods and might be dliminated by either adjusting planting dates or with conserved water in tanks supplied at "short stress" periods. Crops grown in the soil with 300 mm available moisture are not subject to moisture stress. Indeed, relay planting would permit double cropping of short duration plants because late season dependable water is available in this latter soil.

The use of deep rooted plants, which exploit greater soil depth provides another alternative in balancing cropping systems with dependable moisture as presented in this model.

Certainly a systems analytical Technique, such that developed at ICRISAT, facilitates the estimates of crop available water over the growing season. However, provided climatic records, crop consumptive use and soil water storage data are available, useful estimates ablut suitable cropping patterns and management practices can be made.

Biological and Technical :

Bilolgical concepts in cropping systems research require attention to both the above and below soil environment. Principles of technology should relate to the "whole systems" soil, radiation, water and nutrient utilization. The biological-technical complex combines to effect the entire cropping systems's efficiency ; therefore, we chose to develop important concepts in this section consistent with farm operations. The soil, its preparation, seeds and varieties, planting methods, fertility, water management, weeds, pests and diseases, harvest and post-harvest technology are considered in sequence :

The Soil :

Concept : Texture, depth, drainage class, pH and humus content are among the most important soil factors which influence (1) the cropping pattern and (2) management inputs.

Principles : Some principles based on these soil properties include :

(1) Texture : Besides increased water storage, heavy textured soils are better suited for vegetable and cereal crops but less suited to root crops or plants like tobacco and peanuts. Depth is important in droughty areas. Clayey soils with much slower water infiltration rates compared with sandy loams suggest different seed-bed design and longer irrigation schedules.

(2) Drainage Class : Topographic position of the fields in relation to surrounding land is an important factor. When planning cropping systems, fields subject to flooding place severe restriction on the choice of upland crops. Shallow rooted species generally are more tolerant to restricted drainage, though peanuts are sensitive to flooding compared with soybeans.

(3) Soil pH and Salts : While soil acidity can be corrected by lime (an input cost) it may affect choice of crops in a system. In principle, legume species require less acidity and conditions

pH 6.0 compared with most cereals or solonaceous vegetables. Where 'salts' are present, the selection of plants in a cropping system should be based on their sensitivity to salts. Indeed, in Multiple Cropping systems where mixed species are grown, placement of the sensitive crop near irrigation furrows (on seed -beds) relative to more tolerant species is important to minimize salt effects from fertilizer.

(4) Humus content : Poor tilth, often associated with low soil humus, leads to "surface crusts". Where friable seed beds are needed for disease free seedlings and uniform emergence, consideration of cropping patterns based on soil humus content is justifiable.

A principle may be stated : that lower input costs and higher yield outputs follow where cropping system descisions take into account soil properties.

Land Preparation :

(1) In principle, no-tillage systems are inexpensive, favor (by relay planting) quick establishment of the next crop, provide surface resicues to conserve moisture, reduce crusting and provide favorable soil Temperatures.

(2) Certain crops and soil conditions demand seed bed preparations for irrigation and/or drainage. In these instances, decisions should be based over the entire cropping system as initial land preparation affects the second or third Crop. Thus raised seed

beds dry out and influence subsequent soil productivity with benefits to later crops in the system.

(3) Increase in soil bulk density due to much puddling, increases tillage and preparation problems of good seed beds for upland crops.

Varieties and Seeds :

Concept : Markets and/or consumer acceptance provide a basis for designing cropping patterns and selecting plant varieties. Early maturing, photo insensitive, disease and pest resistant varieties with short stems are desirable plant features for Multiple Cropping systems. Useful principles follow :

(1) Plant selection for multiple cropping should consider the radiation and micro climate relationships. Both radiation quantity and quality under intercropping systems vary with with canopy cover, thus shade tolerance to both radiation shifts should be considered in crop choices for such systems.

(2) Figure III. illustrates that sequential cropping with three short term crops is much less efficient in solar energy conversion than either a long term crop or one with relay planting and intercropping varieties which continuously cover the ground.

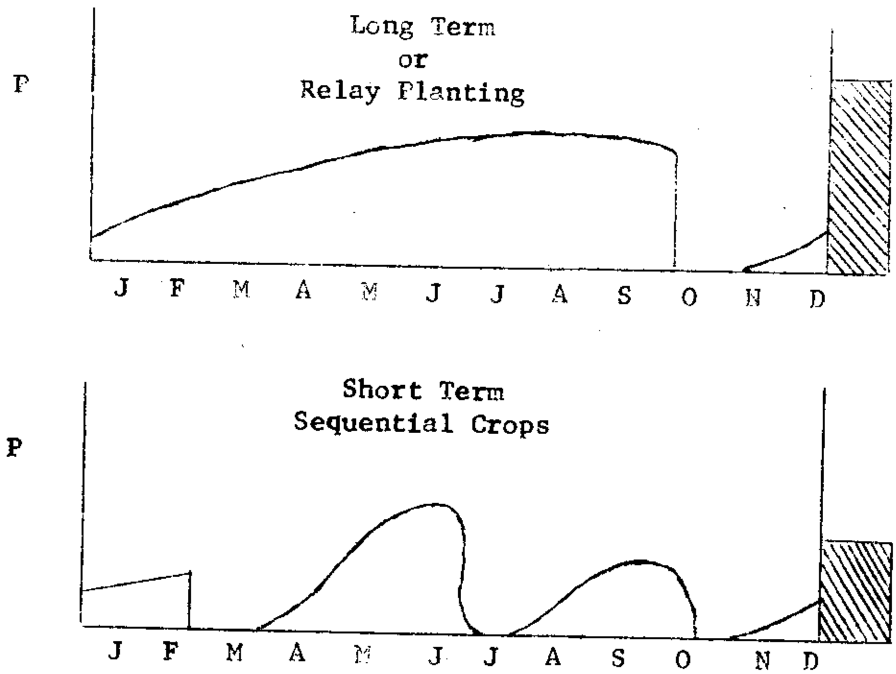


Figure III. Illustration of theoretical photosynthesis or productivity, P, of a single, long-term crop or relay planting as compared with three short-term sequential crops. The height of the bar graph at the end illustrates the relative total annual production of the area under the curves. (Adapted from A. S.A. pub. No. 27)

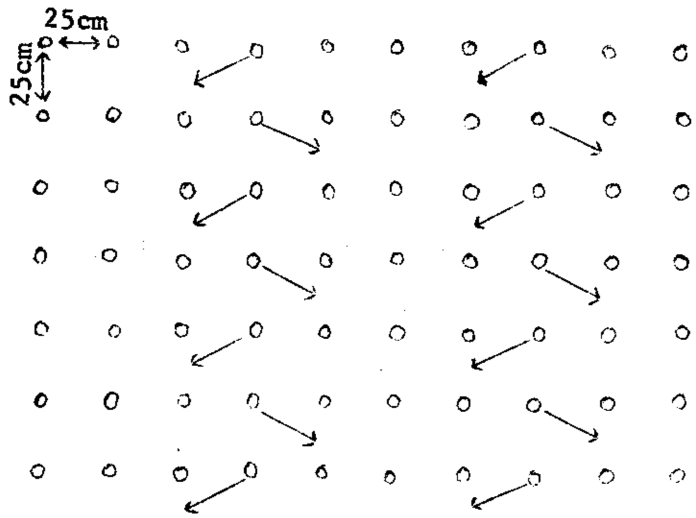
(3) Improved cropping system success depends on a good, reliable seed source of proven acceptable varieties based on markets and consumer preference.

Planting Methods : The appropriate planting methods for cropping systems depend on the principle of conservation including moisture, time, labor and solar radiation.

(1) Traditional, simple, labor intensive planting methods should be carefully examined before being replaced.

(2) Early maturing varieties and improved intercropping technology permit relay planting (transplant or direct sowing) into crops like rice. The rows must be straight and evenly spaced at planting, with non-planted areas selected according to the requirements of the second crop (Figure IV).

Before moving



After moving

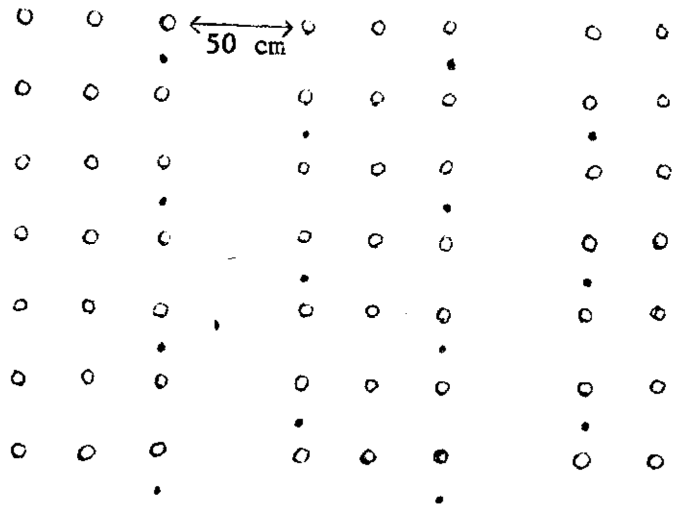


Figure IV. Method of moving the rice plants for the following crop.

(3) Relay planting may reduce first crop yields but utilizes soil residual moisture, provides shade or mechanical support for the intercrop, and synchronizes harvests with favorable markets and weather.

(4) Hand drilled plantings, into non-till seed beds with hoed ridges provide good stands of soybean, mungbean and most cereals. Preemergent herbicides permit direct sowing of vegetables.

(5) Where labor is not a constraint, growing seedlings like tomato and Chinese cabbage in a nursery before transplanting uses solar energy efficiently, reduces period to harvest and often allows another crop to be added in the cropping system.

Fertility and Fertilizers :

Concept : Manage the system in such a way as to insure the crops are sustained with a balanced supply of nutrients at economic levels, using plant/animal residues, legumes and judicial fertilizer inputs dictated by soil tests.

The kind and amount of nutrients, their source, timing and placement are all important.

Principles :

Soil Tests :

(1) Soil fertility can be usefully approximated from soil test data.

(2) Crop removal, leaching, soil fixation and cultural practices readily change the status of available soil nutrients.

(3) Special attention must be given to the dynamics of nutrient supply seasonally, both to (a) determine fertilizer needs and (b) select appropriate crops based on soil Tests.

(4) Fertilizer responses are often governed as much crop species as by soil variabilities.

Plant Nutrient Requirements :

(1) Nutrient requirements of individual species in a cropping system should be studied while planning a cropping pattern. (a) For instance, a soil test of 4 ppm P may be adequate for Rice but

wheat likely would provide an economic response to added fertilizer :. (b) A low potash soil test, (20 ppm) adequate for wheat, suggests an economic soybean response to added potash fertilizer.

(2) (a) Rapid plant growth is associated with considerable demand in soil nutrients, (especially Nitrogen) which varies with plant species. (b) Amount, method and time of N fertilizer based on the species component, rainfall and soil moisture are important.

<u>Sequential Cropping Fertilization</u> : Suggest the following <u>principles</u> :

(1) Apply fertilizer to the economically responsive crop in the system and capture residual fertility in subsequent crops.

(2) A preceeding good legume crop such as soybeans, often reduces by half the N fertilizer needs of the following crop in the system.

(3) Alternating shallow with deep rooted crops favors utilization of soil nutrients at different depths : Examples (Garlic to Sweet Corn; Peanuts to Sugar Cane; Chinese cabbage to Rice)

<u>Intercropping Fertilization</u> : <u>Principles</u> which follow from fertilizing intercrop systems include :

(1) Greatest Yield response from applied N occurs in the Non-legume (corn, through the legume intercrop, ofteh reduces total fertilizer N need.)

(2) A legume component in an intercrop system may be suppressed when N fertilizer is added to the non-legume.

(3) Apply immobile nutrients (P and K) according to soil test results, but apply mobile N fertilizer according to non-legume plant needs.

(4) Randed P and broadcast K fertilizer on the first crop of the sequence are likely adequate for the whole intercrop system.

(5) Side dressing non-legumes with nitrogen fertilizer is often economic.

(6) Side dressing the intercrop non-legume (example corn) with N fertilizer to minimize contact with legume can optimize nutrient use.

<u>Irrigation</u> :

<u>Concept</u> : Good irrigation practices are essential if diversity of cropping patterns is to be successful. Irrigation farming results in increased labor and management but decreased crop failure risk. Important <u>principles</u> include :

(1) Excess irrigation can be as detrimental for upland crops as periods of drought.

(2) Irrigation and land preparation interract so that

a. raised seed beds enable roots to remain aerated.

b. Size, width of seed beds and irrigation ditches must take into account all the crops in the system, whether or not intercropped and whether splash/or furrow watering is planned.

(3) Shallow rooted vegetables like garlic, onion and cabbage require root zones kept near field capacity compared with wheat or peppers which grow well in drier soils. Tomato and beans have intermediate irrigation frequency schedule needs.

(4) In situations of unreliable water supply, individual crops and planting dates must be carefully selected.

(5) On farm irrigation delivery systems should minimize seepage and deliver water only where needed.

Disease and Pest Control :

Concept : Integrated low cost control of pests and Diseases in modern crop and intercropped patterns must be based on previous, companion and subsequent crops in the system.

Pertinent principles in plant protection and multiple cropping include :

(1) Repeated use of similar herbicides and pesticides may result in

(a) tolerance or selective biological adjustment where chemicals lose control effectiveness.

(b) Residual accumulation from phytoxic forming herbicides may injure succeeding crops. Alternatively, systemic pesticides (carbofuran etc.) may benefit following plants.

(2) Crop species, varieties and growing periods all show different degrees of pest and disease susceptibility :

(a) Solanaceous vegetables are more pest and disease prone than cassava or Okra

(b) New varieties can display more tolerance to certain pests and diseases, though dwarf types may be more weed prone.

(c) Perennial crops may host more natural enemies of pests but short maturing annuals have less time for serious insect/disease attack.

(3) Continuous cropping tends to build up pest and disease populations, however, botanically unrelated plants in a cropping/intercropping system provide some protection against pests and diseases.

(4) Planting dates adjusted to coincide with low pest and disease populations provide an effective management tool.

(5) Upon implementing new cropping systems in village communities

(a) synchronize planting dates for each crop in the system to reduce pest and disease host sites and decrease injury.

(b) in the short run, large areas planted to <u>one</u> crop followed by <u>crops</u> of <u>different</u> disease/pest <u>host species</u>, reduce pest populations.

(6) Intercropping, may, through use of non host crop :

(a) provide physical interference of disease/pest migration and weed growth that harm susceptible companion crops.

(b) biochemically emit chemicals (garlic, onion) that adversely effect certain pests, including nematodes (Crotalaria, marigold)

(7) Planned, well timed, diversity control methods of pests and diseases which are ever changing in response to new cropping system provide a Key to pest/disease control.

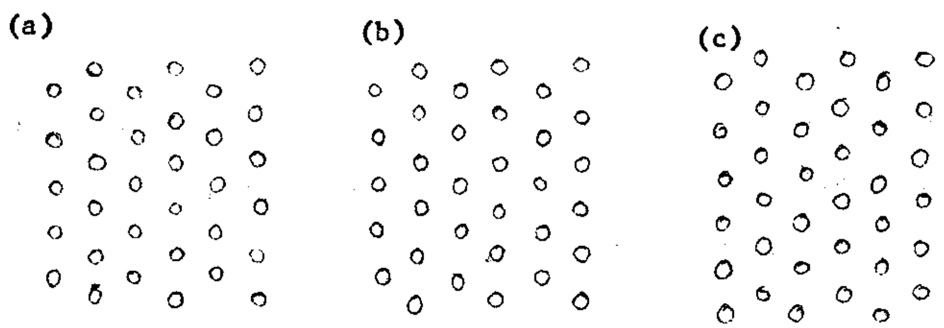
(8) Education programs about the danger of pesticides and herbicides in village communities are essential.

Time and Space :

Concept : Sequential and intercropping systems involve important time-space dimensions with resultant competition and interaction between plant neighbours including plant exudates, transfer of N and metabolites from various soil organisms.

Time-space related principles pertinent to Multiple Cropping include:

(1) The intensity of plant interaction depends on (a) plant density and is (b) proportional to interplant contacts with individuals of different components (Fig. V)



<u>Figure V</u>. Planting arrangements differing in frequency contacts between two crops in intercrop systems. Average contacts (a) 2 (b) 4 (c) 3. (Adapted from A.S.A. special pub. No. 27)

(2) With intercropping, initial interference and competition is between plants of the same component. Gradually, competition will develop at interfaces between plant components due to unsharing of resources (especially light and water) which leads to suppression of one crop.

(3) Season, plant height and leaf inclination, influence amount of light intercepted, leaf area index, and hence degree of shade to which the shorter component is subjected. Selection of plant variety, fertilizer program and date of planting are management tools available to balance component yields.

(4) Root systems differ between species and even among varieties, which, during intercropping, affect component competition for water and nutrient (especially N). Plants with rapid and vigorus roots that over-lap soil depletive zones have a growth advantage.

(5) Under conditions of high N supply the non-legume component is nutritionally favored over the legume, which, combined with shading may suppress the legume.

(6) If a plant individual or a component of an intercrop absorbs less than its share of one "competed for growth factor" it is likely to acquire a corresponding smaller share of all growth factors.

(7) Chemical exudates from living leaves, roots (cucumber, peach) decaying straw (wheat) may affect success in relay planting because of a stimulatory or inhibitory effect.
(Soybean germination appears poor after mungbean and mungbean growth reduced after peanuts.)

(8) Legumes can supply through root nodules some N to a companion crop and significantly reduce N fertilizer needs of a following crop.

(9) The sum of component plant yields in intercropping systems relative to their sole crop yields under similar management and area should provide LER 1. Furthermore, LER[1/] should be measured when component crops are planted together at their optimum sole crop plant densities.

Values of LER 1 may be produced in seversl ways:

(a) Leaf canopies of intercrop components may occupy different vertical layers (Tallest strong light tolerant, shorter shade and high humidity tolerant. (Citrous and Vegetables)

(b) Root systems of vegetables feed from nutrients in surface layers, while soybeans, wheat and peppers roots feed in deeper layers.

(c) If plant species liberate specific toxins or favor beneficial rhisosphere organisms, intercrop growth will be affected.

(d) Errect growing species provide mechanical support for intercrop climbing species (Cow peas and Corn).

(e) Presence of pest and diseases in intercrop systems can lead to L E R 1 where sole crop is badly affected.

Harvest and Post Harvest :

Concept : Improved harvest and post harvest technology is needed under multiple cropping to reduce time, to handle increased volume of different seed varieties and for safer drying and storage.

Fertinent principles include :

(1) Time of seed harvest (especially moisture status) affects seed quality.

(2) Inexpensive mechanical thresher reduces post harvest operations so important when labor constraints occur during short "turn over periods" under Multiple Cropping.

(3) Simple drying methods (including solar energy) at appropriate temperature and moisture levels are essential for quality seeds.

(4) Post harvest and storage facilities provide more flexibility in marketing produce.

(5) Simple, on farm, seed screening and processing equipment under multiple cropping can provide improved marketable products.

Socio - Economic

Concept : Social, cultural and economic factors are central to effective multiple cropping research and testing programs for the small farmer. Some principles may serve as useful guidelines :

(1) The aim of multiple cropping research and testing "to improve the welfare of rural peoples" suggests that development of technologies pivot around the small farmer and his environment, including the socio-cultural economic setting.

(2) Human, and technical constraints eed identification during the inventory stage as both are basic to sound multiple cropping research and testing.

(3) Farmer attitudes and goals relative to allocation of resources (time, labour, capital and management) once knlwn, provide further basis for developing appropriate alternative cropping patterns and Technologies.

(4) Community customs, organization, the availability of services together with family and village progiles once established,

provide baseline for adaptive research and development as well as for subsequent impact studies.

(5) Identified constraints relative to infrastructure support systems (irrigation, transport, credit, farm supplies etc.) serve to help design and test alternate cropping systems and levels of technological inputs appropriate for "local specific" situations.

(6) Evaluation of improved multiple cropping transfer and impact needs to be studied in terms of technical feasibility, social acceptibility, net farm income, compatibility to farmer and infrastructure support.

(7) Evaluation during the implementation Extension phase can determine who benefits from inproved multiple cropping, who are adopters and non-adopters and why.

(8) Education and training, which develop technical competence and social wisdom centred around "the whole farm", are essential components in the elevation of small farmer welfare through improved multiple cropping programs.

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