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IMPORTANCE OF MULTIPLE CROPPING IN INCREASING WORLD FOOD SUPPLIES*

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INTRODUCTION

Multiple cropping describes forms of cropping practices where total primary production from a unit area of land in a farming year is achieved through growing crops in mixture which may be repeated more than once, or sole crops in sequence, or a combination of mixed and sole crops in sequence.

Multiple cropping for food production is in widespread use by farmers in the warmer parts of the world at all levels of agricultural technology. However, the exact form of multiple cropping varies from area to area depending on farmers' total resources. Under conditions of 'low level equilibrium' farming as exists in

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much of the developing world (e.g. Africa, Latin America, parts of India) farming operates with difficulties arising from low capital, unfavourable price relations, unsophisticated markets and rudimentary infra-structure. Here multiple cropping involving the growing of rain-fed crops in mixtures well matches the total resources available to the farmers in maintaining low but often adequate and relatively steady production. On the other hand under conditions of 'high level equilibrium' farming as exists in areas such as the U.S., Taiwan, parts of India, on-the-farm agricultural technology is geared towards commercial production. Here multiple cropping mostly involves the growing of sole crops in sequence but in some cases where farming is both capital and labour intensive due to a high population and an absolute land shortage, growing crops in mixtures has become economically more attractive.

In future much of the food needed by the world's rural and urban population in the areas presently under the conditions of 'low level equilibrium' farming will have to be produced by farming communities under conditions of change in agricultural technology. While efforts by governments to improve institutional and administrative structures and support facilities will play a major part, upgrading the farmers' whole system of cropping will have to parallel

any improvement in resources and services made available. In this context multiple cropping can play an important role, the potential of which has been recognized by many research bodies who in the last decade have initiated investigations into the basic principles involved in various forms of multiple cropping. With the evergrowing need to achieve stable increases in the world food supplies a wider and more intensive use of multiple cropping offers additional means to intensify production per unit area on the existing and potential cultivable area.

PATTERNS AND FEATURES OF MULTIPLE CROPPING

Definitions

Six major multiple cropping practices together with other related terms currently in use are defined in Appendix I. The various patterns of multiple cropping reflect essentially two underlying practices: that of growing crops in mixtures i.e. simultaneous cropping; or growing crops in sequence i.e. successive cropping. Intercropping, mixed cropping and strip cropping work on the former principle, while double (and triple, etc.), relay and ratoon cropping, use the latter. There are several other derived forms of multiple cropping patterns but

these originate through syntheses of the simultaneous and successive cropping practices.

Availability of Water

In vast areas of rain-fed agriculture where full irrigation is an economic impossibility the extent of crop growth is limited by the duration of the wet season moisture supply. In India and Africa settled farming is possible in areas where annual rainfall is greater than 300 mm. In areas with rainfall between 300 mm. and 600 mm. simultaneous cropping is practised with crops of similar maturity, although there is usually a component crop in the mixture which allows a fuller use of the end of wet season moisture. In areas of higher rainfall upto 1000 mm. crop mixtures, especially those involving different maturities, are common. Here the slow growing later maturing components also generally tend to mature under a better end of season moisture conditions. In areas with above 1000 mm. rainfall multiple cropping both on the simultaneous and successive principle, is practised (17, 22).

Successive cropping is possible in climatic areas where conditions for plant growth exist beyond the duration of one early maturing crop. In temperate regions the total growing season is

limited mainly by low temperature (and low solar radiation) in the winter months. However, at less than approximately 40 degrees latitude from the equator, the restriction is usually one of availability of soil moisture. Within these warmer regions with a long wet season, as in the humid tropics, or a shorter wet season as in the dry tropics but with irrigation facilities, crops can be grown through much of the year or all the year round. It is in such areas that a strong association with multiple cropping emerges (9), and rice in monoculture more than any other crop is involved in areas closer to the equator while rice in combination with other crops e.g. wheat, in areas away from the equator. However, the cropping intensity index varies from area to area and country to country. The cropping index in India is about 115 over about 20 m. ha. which can be double cropped, out of approximately 100 m. ha. In Taiwan the cropping index is 185, with certain districts as high as 230 though figures for individual fields may exceed 400 (9).

Utilization of Space and Time

Crops may be grown successively, one after another, so that time is used to obtain more production; or crops can be mixed and

grown together simultaneously. With the latter, since different crops have different growth requirements, a mixture of crops of similar maturity can have a higher total productivity rate than a single sole crop. However, crops commonly used in mixtures usually also differ in maturity, so their growth requirements are further separated in time and thus competition between them is less.

The simultaneous patterns of cropping aim at utilising both extra time and spatial arrangements of component crops, and one species may even provide support for another as in the case of climbing beans and maize (7). In a successful crop mixture of both similar and different maturities the sum of the inter-crop competition should be less than the sum of the intra-crop competition of the components crops when grown sole. Gain originates in crop mixtures because either individual plants yield more and/or higher total plant population densicies are possible. In mixtures of crops of similar maturity yield advantages accrue basically through a lower 'instantaneous' inter-crop competition in space, both aerial and edaphic. In mixtures of crops of different maturities yield advantages accrue through a low inter-crop competition in space and time for the more rapidly growing, early maturing, components and through a lower intra-crop competition in space and time for the slow growing, later maturing, components.

The successive patterns of cropping aim at multiplying the net return per unit area by growing extra crop(s). Time is therefore the extra dimension used. The breeding of high yielding, early maturing crop cultivars has greatly contributed to the flexibility of successive cropping patterns. For example, the replacement of the photosensitive Kharif (wet season) sorghums with early maturing hybrids in India has allowed double cropping where only single cropping existed before. Further where single cropping already existed, it has permitted earlier planting, with consequent higher yields of the second crop (Rabi post-monsoon, residual moisture crop) such as wheat, chickpea, safflower, linseed and sunflower (17, 21). The principles used to increase yields of sole crops can be more easily transferred to successive cropping, where crops are usually grown sole, rather than to crop mixtures. However, a note of caution has to be sounded when adopting new successive cropping sequences due to possible negative carryover effects from one crop to another. The first crop may adversely affect the performance of the second crop by an undue depletion of nutrients or soil moisture reserves and increase in the population of pests and diseases, particularly critical in monoculture sequences. On the other hand complementary effects can be noted with sequences involving legumes, and pest and disease control when different crops are used.

The principles of yield increases resulting from a better use of space in mixtures is complementary to utilising time with crops in sequences. Theoretically, therefore, maximum cropping should be obtained with sequences of high yielding crops in compatable mixtures. In practice, an analogy of this pattern has evolved in relation to the traditional resources where several crops are planted and harvested in mixtures at different times (4, 22).

Yield Advantages in Crop Mixtures

The extent of the extra contribution to production per unit area from crop mixtures has been particularly difficult to define in surveys because the land equivalent ratio (LER) of a mixture is not readily apparent without the corresponding yield figures of all the component crops in the mixture grown as sole crops under similar management. However, LERs of upto 1.6 have been reported for farmers fields in northern Nigeria (4).

Experiments have been conducted to discover if and how crop mixtures can be improved and LERs of upto 2.0 have been reported (e.g. 1, 11, 14, 16, 21). Cultivars bred for high yields under sole cropping show less inter-plant competition which also makes

them more favourable for growing in mixtures provided any shift in the inter-plant competition equilibrium in mixtures is restored by adjusting the relative crop plant densities. Work at IRRI (14) has indicated that some mixtures show a higher LER at low level of management while others eg. rice/maize respond to good management. Further instances of good responses at higher production levels have been demonstrated with sorghum/millet/cowpea mixture (2), sorghum/millet/maize (3), sorghum/beans (20) and maize/beans (24).

High yielding cultivars tend to give optimum yields over a wide range in population density and at high plant densities in mixtures row widths are less critical. This facilitates intercropping and contributes to better utilization of space. Work comparing intercropping with mixed cropping (8, 10) has indicated that there need not be a substantial loss in reorientating mixed crops into rows, which patently has many advantages and is a necessity to allow more improved production techniques to be applied to mixtures. On a row basis many crop specific cultural operations are possible from sowing to harvest; and there is a wide scope for using animal and motorised power in inter-crops without having to resort to strip cropping, where the benefits from crop contact over space and time are less.

Since yield levels have been shown to be higher with crop mixtures in semi-arid tropics, where availability of water for crop growth is often limiting, total crop water use efficiency of mixtures may well be higher particularly for the wet season as a whole (4). Similarly, investigations into nitrogen use efficiency have indicated with some exclusions (18) that mixtures can make better use of nitrogen than sole crops (14, 15). Further, weed control and use of total available labour has been shown to be better in crop mixtures (4).

Security Factors in Multiple Cropping

A significant feature of multiple cropping is that of a greater dependability of return compared to sole cropping. This is important at all levels of production but especially to small farmers at low yield levels where alternatives to production are much more restricted and the farmer therefore has to be more certain that his investments of labour and capital (if any) are protected. In the tropics, at low levels of production, it has become abundantly clear that the adoption of sole cropping practices for many food crops offers less dependable returns (10, 19, 22, 23). In this context increases in production are more likely to come through multiple cropping which satisfies the farmer's security motives.

Successive cropping is intrinsically more secure in providing some measure of return because two (or more) crops will be attempted during the year. In the rain-fed areas the potentiality of multiple cropping attracts the development of soil and water resources which is accompanied by an array of stabilising features such as less risks of drought and erosion.

A crop mixture is more dynamic biologically than a sole crop and is less likely to succumb to adversities of nature. Reduced performance of some of the component crops may be compensated by those remaining. There is good evidence (6, 12, 14) that pest attack may be lower on crops grown in mixtures involving maize, cowpea, pigeonpea and probably other legumes. This is possible also for diseases where the severity of attack is proportional to the host plant density. Further, there is some evidence to suggest that the pest population dynamics may be more stable than in sole crops (14). While verification of lower pest incidence in mixtures at higher levels of production is required, it remains likely that pest control could be easier in some mixtures.

MULTIPLE CROPPING AND FARMERS' RESOURCES

The Present Scene

The actual form of multiple cropping used and benefits a

farmer derives from it is dictated by the farmer's yield sustaining resources on the farm and his own understanding of how best to achieve maximum profit and security within the limitations of his total environment. In areas where the rainfall climate is long and favourable enough to grow more than one crop of different maturities simultaneously or successively, or where irrigation is available the potential benefits of multiple cropping have been long appreciated and are being realised. Where farming has become capital intensive, in such areas production is at a high level even in the developing world. However, it is in the dryland areas of the developing world with low production where the benefits of multiple cropping at a high level of production are yet to be realised on a large scale. The natural reasons for the fluctuations of world food supplies are adversities of climate and weather. Most vulnerable to these factors are the 'low level equilibrium' farmers whose failures to meet basic production requirements in poor years strain available food reserves most. To consider the potential of multiple cropping in increasing world food supplies, it is essential to recognise that the problems of increasing production in areas where farming is already capital intensive and labour saving or labour intensive, are markedly different from those of increasing food supplies in areas where farming communities depend solely on their own labour (with or without animal power) in agriculture for

survival. It is these latter areas, and these comprise of about 80 per cent of the farmers in the poorer countries, where cropping practices have to improve not only to produce more food but to provide productive work for the rural population, food for the urban population, raw material for industries and export, markets for the products of indigenous industries, and provide funds for general rural development. Hunger has been often thought of as the main problem of these areas in the developing world, but it has long been evident that most of the poorer countries' hunger is but one facet of poverty along with many other disadvantages (5). It is further evident that as human populations have increased in the poorer countries, the output of food has increased with them, so that except in certain parts of Africa, estimated average output of food per head has generally risen (5).

The Green Revolution

The green revolution with rice and wheat is commonly associated with high yielding varieties, some of which can indeed outyield the traditional cultivars even when the cultural practices remain unchanged. However, the impact of new varieties of rice and wheat on production has occurred mainly through improved conditions of production, particularly in respect to irrigation, fertilizers

and control of pests and diseases. Consequently, the logistics of the green revolution have had to include schemes to ensure that the necessary inputs are available to the farmers in the right form, that the farmer has means to buy them on fair terms and that there is a reliable market at the end of the season at a price sufficient to ensure a profit and an adequate incentive. In other words, the use of high yielding varieties and the successive cropping practices in much of the green revolution areas is interlocked with better total resources and services made available (5).

TECHNICAL RESEARCH AND PROSPECTS

In irrigated agriculture multiple cropping (successive cropping) practices are usually more technologically advanced even in the developing world. The use of irrigation requires complementary land development and soil and water management practices which also create a stable framework in which improved cultural practices become reliably more profitable and newer techniques can be more easily adopted. In the rain-fed agriculture in the tropics, rainstorm systems and soil water regimes are such that crop production is caught between drought and leaching (and excess water).

Further, the high energy load and concentrated nature of individual rainstorm systems present serious erosion hazards during the whole wet season on all types of soil. All this leads to problems of soil, water and crop management largely unknown under the gentler rainfall conditions of the temperate and sub-tropical climates. Proper understanding of the characteristics of rainfall and its management, use and conservation is a fundamental requisite for creating a stable basis for improving production. Control of soil erosion, improvement of soil moisture penetration and retention, reduction of run-off and harvesting that which does occur for re-use during the wet season or extending the growing season, are basic concepts (13). Within this context multiple cropping with its quicker, greater and longer crop cover offers a better and stable yield producing system (16). However, a proper understanding of nutrient, pest and disease balance and their control and management is needed in both the semi-arid and humid tropics. The possible benefits of legumes in mixtures and sequences must be more clearly studied in relation to the whole question of the nitrogen cycle. Since the success of multiple cropping depends largely on the utilization of time, its management becomes important in terms of operations needed in respect to the seasons and state of the component crops. The use of power (animal and/or motorised) and implements has been recognized as being an important

input in relation to the timeliness of operations, reducing drudgery of farming, removing labour bottlenecks, and generating employment through increased production. However, more information is needed on the economics of various sources and types of power and implements which are likely to be suitable for multiple cropping. Finally, all the above aspects of multiple cropping needs to be considered in the overall context of the cropping system and it is here that the results of cropping systems research supported by appropriate socio-economic studies such as that conducted at IRRI, ICRISAT, CIAT, IITA, and national centres is most needed.

The prospects of increasing world food supplies through multiple cropping in the rain-fed farming areas of the poorer countries must be seen in perspective i.e. it is only one element in the fight against poverty. Rural populations in these areas will continue to increase for many years to come and if their wellbeing is to improve, agriculture will have to provide more productive work and better food the year round than it does now. Multiple cropping at high production through the use of intensive capital investments, heavy farm machinery and labour saving means is unlikely to offer a solution to the large majority. The object will be how to use productively as much of the labour available with limited capital. The use of animal power and/or mechanisation

should be aimed at increasing labour productivity not by reducing the total labour required, but by reducing labour bottlenecks particularly that of weeding and other activities related to the pronounced labour peak early in the season, so that labour may be more productive at other times in the season. Low capital mechanisation which is production enhancing, and where possible, employment generating will therefore be more appropriate. Multiple cropping, particularly simultaneous cropping is labour intensive and can be more productive per unit area, which, for many of the populous regions with absolute land limitations is a more realistic yardstick to use when taking into account the social objectives and economics of human labour, although production per unit total costs will always be of prime importance for production geared toward commercial markets.

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APPENDIX I

MULTIPLE CROPPING - Growing more than one crop on the same land in one year. Within this concept there are several patterns of crop arrangement in space and time:

INTERCROPPING - Growing two or more crops simultaneously on the same land in different but proximate rows.

MIXED CROPPING - Growing two or more crops simultaneously intermingled on the same land with no distinct row arrangement.

STRIP CROPPING - Growing two or more crops in different strips wide enough for independent cultivation.

DOUBLE CROPPING - Growing two crops in sequence, seeding or transplanting one after the harvest of the former (same concept for TRIPLE CROPPING, etc.)

RELAY CROPPING - Growing two (or more) crops in sequence, seeding or transplanting the succeeding one before the harvest but after the flowering of the former. If the flowering period of one crop overlaps with presence of the succeeding crop the combination becomes mixed or intercropping.

RATOON CROPPING - The cultivation of regrowth from stubble following a harvest not necessarily for grain.

Other practices related to multiple cropping requiring definition are:

MONOCULTURE - The repetitive growing of the same crop on the same land.

SOLE CROP - One crop variety grown alone in pure stands at normal density. (Synonymous with solid planting).

CROPPING PATTERN - The yearly sequence and spatial arrangement of crops, or of crops and fallow on a given area.

CROPPING SYSTEM - The cropping patterns used on a farm and their interaction with farm resources, other farm enterprises and available technology which determine their make up.

CROPPING INDEX - The number of crops grown per annum on a given area of land x 100 (applicable to successive types of multiple cropping).

LAND EQUIVALENT RATIO - The ratio of the area needed under sole cropping to one hectare of inter- or mixed

cropping at the same management level, to give an equal amount of produce. LER is the sum of the ratios or fractions of the yield of the intercrops relative to their sole crop yields.

MAXIMUM CROPPING - The attainment of the highest possible production per unit area per unit time without regard to cost or net return.

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