Intercropping on an Operational Scale in an Improved Farming System

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Abstract

Mixed cropping, or intercropping, evolved in traditional agriculture where it has been practiced at a low level of technology largely for risk reduction Recent research has shown substantial benefits from intercropping at medium to high levels of technology, however, due to several factors, including the lack of operational-scale research, sole-cropping technology is being promoted by national programs, and the potential benefits of improved intercropping are not being achieved Therefore, scientists should take the next step of conducting research on an operational scale to uncover and solve possible problems and constraints Since the farmer in the semi-arid tropics has limited capital and land, scientists should provide him with the necessary information to capitalize on the intercropping benefits and the synergistic effects of nonmonetary-improved management to use in combination with his costly monetary inputs

Intercropping[1] and mixed cropping[2] evolved in traditional agriculture of tropical and subtropical countries and have been practiced for centuries In traditional agriculture, mixed cropping has usually predominated particularly in the early stages, and has been practiced at a low level of technology largely for risk reduction (Norman 1975) Even though mixed cropping is centuries old, the modern concepts of intercropping are relatively new, and very little research has been conducted in intercropping until recently

There are many reasons for the neglect of intercropping research including the following

1 With the advent of mechanical harvesting, especially in developed countries, the practice of intercropping was abandoned
2 Since intercropping is generally associated with traditional agriculture and subsistence farming at low inputs, breeders concentrated on developing genotypes for sole crops and not for intercropping
3 There was a general belief that intercropping advantages were manifested only at low levels of inputs and technology However, recent research has shown that there are substantial yield advantages of intercropping at medium to high levels of technology (Krantz et al 1976, ICRISAT 1977e)

Even where experiment stations have conducted research showing substantial yield advantages of intercropping at medium to high levels of technology with high-yielding varieties the extension programs for high yielding varieties have usually been launched using sole-cropping systems Thus, farmers who normally intercrop with their local varieties have been strongly encouraged to abandon this practice and sow the high-yielding varieties as sole crops Unfortunately, then, sole cropping has become identified with improved technology There are various possible reasons for this situation

1 The extension of sole-crop technology is simpler and easier than that of intercropping technology

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1 In intercropping two or more crops are grown simultaneously on the same land in different but proximate, rows

2 In mixed cropping, two or more crops are grown simultaneously in the same area with no row arrangement

2. Intercropping research at experiment stations is almost always carried out in small plots under carefully controlled hand operations. Due to the lack of research on an operational scale, the more complex intercropping technology may need further adaptation before it is ready for farmer adoption.

Research in small plots under controlled experiment station conditions may show alternate row arrangement of intercrops, such as a cereal and pigeonpea, to give the greatest yield advantage. However, the alternate row pattern presents many problems on an operational scale under farm conditions, such as (1) inefficiency of applying needed N or plant protection chemicals to one row of cereal and not to pigeonpea, (2) the problem of hand harvesting the cereal at physiological maturity without damaging the pigeonpea which has spread out and is in the flowering stage, and (3) the problem of handling regrowth of sorghum which competes with the pigeonpea for residual moisture in the soil at the critical reproductive stage of growth.

Since many farmers in developing countries are acquainted with intercropping at low levels of technology, and research has shown that substantial yield advantages persist at high levels of technology, it behooves us as scientists to go one step further and work out principles of the best production practices which can be used by farmers on an operational scale.

Operational-scale Research at ICRISAT

The aim of intercropping research is to optimize the use of natural resources including light, water and nutrients (Donald 1963). However, if intercropping is to be fitted into improved farming systems, other factors must be considered. These factors include the human capital and power resources available to the farmer. Thus, we must ask some questions. Is the specific intercropping system operationally feasible with the farmers' present resources? If not, what additional resources or inputs will be needed? Will the weed and insect problems be greater or less than with sole crops? Do the crops fit his needs, and is there a market for his surplus? Does intercropping fit in with other facets of his farming system?

In the Farming Systems Research Program at ICRISAT, operational scale research was started a few years ago and is being carried on as a complement to small plot research. The operational scale research is being carried out in watersheds (catchments) that were established to study the effect of different soil, water, and crop management systems upon water balance and soil and water conservation. Thus, the operational scale research is conducted under many different land management systems, such as the traditional field or the contour bunded system with traditional implements, flat cultivation with improved implements, and the bed and furrow system at varying slopes created by adjusting furrow direction within the watershed. This provides an opportunity to investigate and solve many operational problems under a wide range of soil and water management systems and cropping systems using animal drawn implements.

In the early years, a wide range of crops was investigated in inter-, relay, and sequential cropping systems. These included (1) pigeonpea intercropped with sorghum, pearl millet, and setaria and (2) sorghum, pearl millet, sunflower and maize followed by relay and sequential crops of chickpea, safflower, sunflower, and sorghum. In this operational scale research, many problems that did not show up in small plot experiments were discovered, and as a result, certain crops and cropping systems were eliminated. Some examples of these are as follows:

1. Relay cropping was eliminated in the 75 cm beds because of damage to the standing cereal or sunflower crop and the problems of cultivation and planting with present equipment.
2. *Kharif* (rainy season) pearl millet was eliminated in the deep Vertisol watersheds due to the difficulties in harvesting during the rainy period in these montmorillonite clay soils. Kharif sorghum was reduced to a minimum for similar reasons. Analysis of the rainfall data indicated that the possibility of having the required 3 consecutive days for harvesting these crops was very small (Table 1). This highlighted the need for mold and weathering resistance in sorghum and pearl millet genotypes.
3. Although setaria appeared to be compatible and mutually noncompetitive with the

Table 1 Field workday probabilities at maturity of sorghum and millet crops in two soil types at Hyderabad

Crop	Maturity (no of days)	Number of 3 consecutive work day probabilities in	
		Alfisols	Vertisols
Millet	65–70	50	4
Sorghum	90–100	77	29
Sorghum	130–150	93	83

pigeonpea intercrop it was eliminated because of low yield low price and limited market Sunflower was eliminated because of parrot damage and harvesting and drying problems

4 Tractor use was eliminated and bullock power only was used in order to develop feasible farming systems using the same power source as that available to the farmers of the SAT

5 The 75 cm beds and furrows were replaced with 150 cm bed and furrow system (Reasons for this change are given in a later section)

Soil and Water Management and Cropping Systems

Vertisols

After several years of operational scale research on a field scale the following guidelines for soil water and crop management systems have been developed and found successful on the deep Vertisol watersheds

a Establish a 150 cm bed and furrow system at about 0 6 % slope after minor smoothing to erase the microrelief (These beds can be established on a semipermanent basis and maintained by minimum tillage)

b Till beds using toolbar with left and right hand plows immediately after the harvest of the last crop of the growing season to kill weeds and stubble and cover the soil cracks with a cloddy mulch thus conserving residual moisture in the soil profile

c After premonsoon rain has moistened the clods and the soil has redried sufficiently to avoid compaction harrow if necessary to kill weed seedlings and use a ridger cum bed former to reshape the beds This completes the seed bed preparation during the dry season well ahead of planting time with minimal tillage and soil compaction Premonsoon land preparation also reduces peak power and labor demands during the early monsoon

d About 7 to 10 days before the expected onset of the rainy season fertilize and plant dry any crop which can be planted 5–7 cm deep (Fig 1) This includes crops such as sorghum pigeonpea maize and cowpea In the past 6 years planting such crops in dry soil has been successful Dry planting is much faster and less hazardous than attempting to plant after the rains start on these montmorillinitic clay Vertisols which become very sticky when wet (In cases where planting was necessary after the onset of the monsoon the time required for planting was greater and poorer stands were obtained) Because of the high water holding capacity of these soils and the relatively deep planting required no germination will take place after small showers of 5–10 mm When there is sufficient rainfall to germinate the seed at the 5–7 cm depth there is sufficient soil moisture to keep the plant alive at least 10 15 days with no further rains

In most of the Vertisol watershed units two cropping systems (inter and sequential cropping) were used with two replicates The positions of the two systems were rotated each year

The intercrop system consisted of medium duration pigeonpea (180–190 day) and a short duration maize (85–95 day) intercrop At physiological maturity the tops of the maize plants were cut just above the ear level and the green fodder was used for feed This removed the major shade competition from the pigeonpea and allowed it to spread and approach full vegetative growth Beets (1975) reported similar practices in Indonesia to facilitate early relay planting The maize cobs were allowed to dry in the field on the stalk and were harvested whenever convenient Immediately after the removal of the maize cobs the beds were tilled using the left and right hand plows on the high clearance wheeled tool bar to kill weeds and partially incorporate the maize

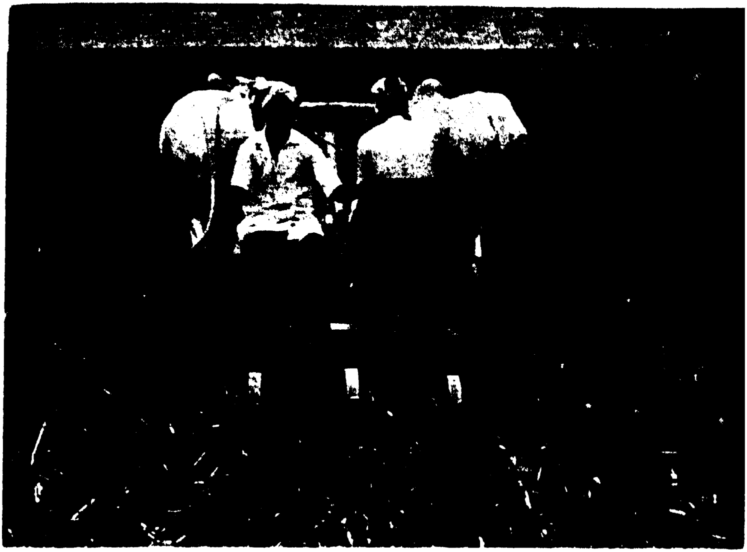

Figure 1. A pigeonpea/maize intercrop being planted on beds in dry Vertisols just before the rainy season.

stalks. Since this was done before the pigeonpea flowering time, it did not damage the pigeonpea plant.

The sequential crop system involved sole maize (105–110 day duration), which was harvested by removing the ears from the standing stalk and drying them in cribs. The fodder was then removed for feed. The land was then cultivated by bullocks and hand weeded, where necessary, to remove large weeds, in preparation for planting of the relay crop of sorghum, chickpea, or safflower.

Alfisols

a. Establish the bed-and-furrow system on a semipermanent basis after land smoothing as in the Vertisols (Fig. 2).
b. In a single-crop system, till the beds with left- and right-hand plows immediately after crop harvest to kill weeds and form a rough cloddy surface, which is receptive to premonsoon showers and resists possible wind erosion.
c. In sorghum/pigeonpea intercrop, till immediately after sorghum harvest with left- and right-hand plows to kill weeds and uproot sorghum stubble on each side of the pigeonpea intercrop.
d. Where Alfisols are double cropped and are very dry and hard after the second crop, the primary plowing may have to be delayed until after the first early monsoon rain.
e. Since Alfisols have a low water-holding capacity, delay planting until after the rains have moistened the soil to a depth of 15–20 cm.

Procedures Used on Both Soils

a. Cultivate and hand weed early, as soon after crop emergence as weather permits. In high-rainfall areas, where early weeding

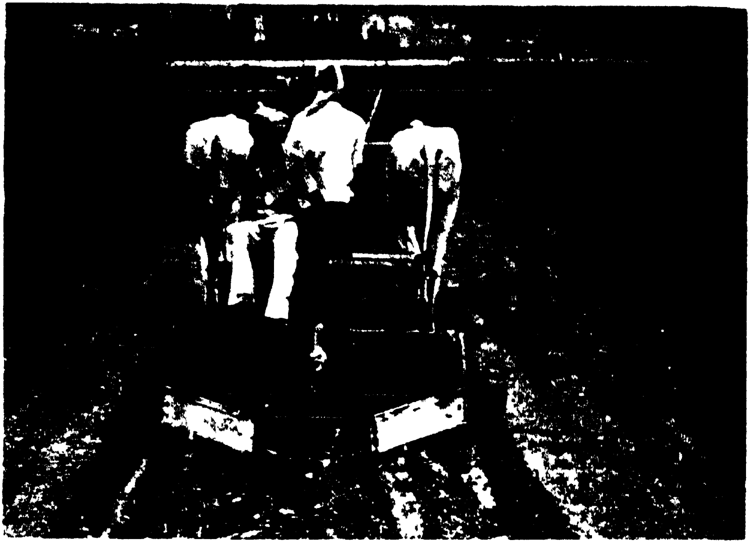

Figure 2 Ridger cum bed former reshaping beds for the third year

is difficult use a minimal application of preemergence herbicide for early weed control in deep Vertisols

b In intercropped systems involving a medium duration cereal harvest the cereal as soon as possible after physiological maturity to remove light and moisture competition from the long duration crop

c Where ratoon cropping of sorghum is planned harvest the heads and cut the stalks just above ground level soon after physiological maturity

d Where double cropping is practiced remove the monsoon crop as early as feasible and cultivate and plant between the standing stubble This technique has worked successfully and greatly reduces the power demand and time required for land preparation Saving energy is an important factor when all cultural operations are carried out by the use of bullock power saving time increases the length of the growing season for the second crop and conserves soil moisture for germination of the postmonsoon crop

Relay and Sequential Cropping

Some crops such as *rabi* (postmonsoon) sorghum and pigeonpea are benefited by early planting as relay crops before the normal harvest time of the rainy season crop such as maize However operationally it is very difficult to relay plant in between standing crops The planting arrangement used in the broadbed and furrow systems offers an opportunity for developing operationally feasible relay planting systems

An experiment was initiated in which the two maize rows in every second bed were harvested for green cobs and green fodder thus providing an opportunity for relay planting with the wheeled tool bar in a 235 cm space between the standing maize plants In all systems chickpea was planted after maize grain harvest at physiological maturity in the remaining 65-cm space. Thus, chickpea occupied 22% of the space of the postharvest season while the pigeonpea, safflower, or sorghum occupied 78% of the space. Since all yields are recorded on the hectare basis, it is possible to add the monetary values together to get the total monetary value. The aim of this experiment was to explore various aspects of the problems involved on an operational scale to determine production opportunities and operational constraints. After 50% of the maize was harvested for greencob and green fodder, the 235-cm area between the standing maize plants was cultivated and planted with the wheeled tool bar and no operational difficulties were encountered.

In the treatment in which 50% of the maize was harvested for greencob and the rest for grain, the total monetary value was Rs. 7510, which was 60% greater than the monetary value of the plots harvested for grain only, due largely to the higher monetary value of the maize greencob (Tabel 2). Likewise, the relay-planted pigeonpea produced 180 kg/ha more than the sequentially planted pigeonpea. However, the companion chickpea crop produced 140 kg/ha less with the relay pigeonpea compared to the sequential pigeonpea. Thus, there was only a slight net advantage for relay planting. It is recognized that there is a limited market for maize greencobs. However, where a market is available, the system appears to be promising and the experiment is being repeated in 1978.

Investigations on Bed-and-Furrow Systems

Systems involving graded (150-cm) beds separated by furrows that drain into grassed waterways appear to fulfill most of the requirements of soil and water conservation and management (Krantz et al. 1978). The improved surface drainage function of beds and furrows over that of flat cultivation has been shown by Chowdhury and Bhatia (1971) and Krantz and Kampen (1973). An example of the type of system envisaged is illustrated in a schematic drawing (Fig. 3).

During the 1975 season, a wide (150-cm), graded (0.4% slope) bed-and-furrow system was compared to a 75-cm system on the Alfisols. In these soils, the 75-cm beds were unstable, and cross flow and erosion were encountered during high-intensity storms, especially in slight depressional areas. This problem was overcome by the use of a 150-cm bed-and-furrow system. In order to evaluate the effect of different land-management treatments on deep Vertisols, an experiment was established in watershed no. BW5A using relatively large plots (0.3 to 0.4 ha) to study relevant

Table 2. Effect of time of maize harvest and relay and sequential planting upon gross yields and monetary value on a deep Vertisol, 1977–78 (average of four replications).

	Maize			Pigeonpea[a]				
Treatment	Grain	Green cob	Chickpea	Relay	Seq.	Safflower	Sorghum	Total
Grain yield (kg/ha)								
1	1735	29 360[b]	205	863	–	–	–	
2	1650	28 320	213	–	–	316	–	
3	3310	–	345	–	683	–	–	
4	3310	–	302	–	–	–	660	
Monetary values (Rs/ha)								
1	1579	3 524	461	1942	–	–	–	7510
2	1502	3 399	479	–	–	758	–	6140
3	3012	–	776	–	1537	–	–	5330
4	3012	–	680	–	–	–	561	4250

a. Relay plantings of pigeonpea and sorghum were made on 8 Sept (sorghum was severely damaged by cutworms and was replanted to safflower). Sequential plantings were made on 22 Sept.

b. Green cob yield given as number/ha.

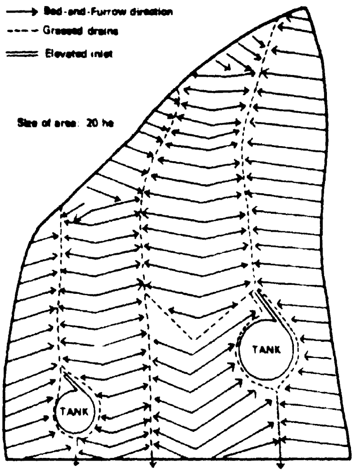

Figure 3. A diagrammatic sketch of a cropped watershed with graded bed-and-furrow system, grassed waterways, and tanks. In this system the excess water is allowed to flow through the small furrows to a grassed drainage way and is then safely conducted to a tank and/or an outlet. The velocity of flow of water is controlled by the direction and slope of the furrows, and the occurrence of erosion causing overland flow is avoided. (This map also shows the use of a diversion channel to lead water from the center watershed unit to the larger tank in the right-hand watershed.)

factors such as runoff, erosion, drainage, operational requirements, and yields. There was a slight increase in the rainy-season maize and the postrainy-season chickpea due to the broad-bed system (Table 3). The 75-cm beds were also found to have very limited flexibility to accommodate the wide range of crops grown in the SAT. With the 150-cm beds, it is possible to plant two, three, or four rows per bed at 75-, 45-, and 30-cm row spacings, respectively. Flexibility of the broader beds is illustrated in Figure 4. The broadbed-and-furrow system can be easily prepared and maintained with animal power.

Table 3. Effect of land management on crop yields and total value on a deep Vertisol (means of 1976–77 and 1977–78).

Land treatment	Yields (kg/ha) Maize	Chickpea	Value[a] (Rs/ha)
Flat planting	2690	650	3650
Narrow ridges (75 cm)	2790	590	3620
Broad beds (150 cm)	2800	830	4090

a. Total value of yield of maize (Rs. 0.89/kg) and chickpea (Rs. 1.93/kg).

In deep Vertisol watershed units, three watersheds in the bed-and-furrow system (BW1, 2, and 3A) were compared with adjacent flat culti-

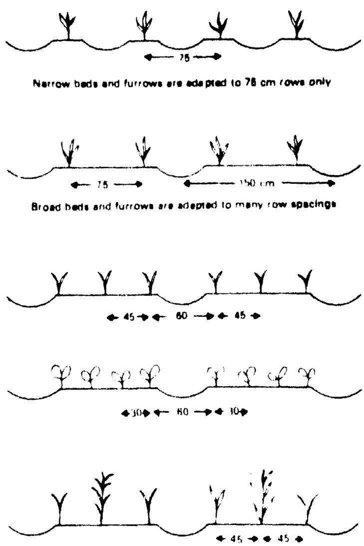

Figure 4. Some possible cropping patterns on narrow and broad beds.

Table 4. Mean monetary values (Rs/ha) of flat and semipermanent bed-and-furrow systems on Vertisol watersheds using improved technology in 1976 and 1977.

Water-shed No.	Land management system	Year	Intercrop			Sequential crop			Means	
			Maize	Pigeonpea	Total	Maize	Chickpea	Total	Both systems	Both years
Deep Vertisols										
1,2,3A	Beds	1976	2840	2080	4920	2730	960	3690	4300	
1,2,3A	Beds	1977	2270	2770	5040	2880	2400	5280	5160	
Means										4730
3B,4B	Flat	1976	2530	1680	4210	2300	570	2870	3540	
3B,4B	Flat	1977	2450	1810	4260	2790	2200	4990	4620	
Means										4080
LSD (0.05)										280
CV (%)										9.2
Shallow to Medium-deep Vertisols										
7B,C,D	Beds	1976	2020	1570	3590	1970	560	2530	3060	
7B,C,D	Beds	1977	2460	1630	4090	2410	1560	3960	4030	
Means										3550
6C,6D	Flat	1976	1960	1490	3450	1570	560	2130	2790	
6C,6D	Flat	1977	2310	1880	4190	2290	1390	3680	3940	
Means										3370
LSD (0.05)										NS
CV (%)										15.6

vated watersheds (BW3B and BW4B). The average monetary values for both the inter- and sequential cropping systems under the flat and the bed-and-furrow systems for 1976 and 1977 are given in Table 4. In the deep Vertisols, the average monetary value of each of the four crops was consistently better with graded beds and furrows than with the flat system. The mean monetary value of all combinations for the bed-and-furrow system was Rs. 650/ha greater than for the flat system. This difference was highly significant. The monetary trends were less consistent in the shallow to medium-deep Vertisols than in the deep Vertisols and the increase of bed-and-furrows over the flat systems was not significant. (Table 4).

The beds function as "mini bunds" at a grade which is normally less than the maximum slope of the land. Preliminary data at ICRISAT Center indicate that the optimum slope for a bed-and-furrow system is 0.3 to 0.6% in Alfisols and 0.4 to 0.8% in Vertisols. When runoff occurs, the velocity is reduced and infiltration opportunity time in the furrows increases. Thus, the semipermanent bed-and-furrow system provides water control for in situ soil and water conservation throughout the year. The conservation and utilization of water can give an immediate impact on crop yields. Thus, it is important to develop cropping systems, including intercropping, relay cropping, and sequential cropping, that will capitalize on the improved resource for improved crop production. With improved water-resource development and utilization in the semi-arid tropics, it is often possible to grow two good crops in place of the one mediocre crop that is commonly grown in traditional agriculture. This requires integration of a number of cropping and management systems into a complete farming system.

This increased intensity of cropping will require more total labor and animal power than the traditional systems but not necessarily any higher peak demands. Operational-scale research carried out at ICRISAT has developed procedures for land development and preparation during the hot dry premonsoon season when no crops are grown. In this manner, the power and labor demand is spread out and high peaks are avoided.

Integration of Various Facets of Improved Technology

To achieve full benefits of improved cropping systems and resource development and management, all facets of farming systems must be considered. In the development and implementation of improved technology there are many steps involved. If one attempts to research each of the individual factors, the total number of combinations becomes unmanageably large. The many facets were grouped into the following four phases: variety, fertilization, soil and crop management, and supplemental irrigation.

In 1976, an experiment, was conducted with sorghum, involving a comparison of "traditional" and "improved" technology in Alfisols. During the rainy season, the rainfall distribution was fairly adequate and uniform and no supplemental irrigation was used. Thus, only the first three phases were considered. There was a significant response to improved fertilization. Improved variety and improved management as single factors showed an upward trend but were not significant; however, treatments involving two or three steps in combination were highly significant. The yield increase from the three steps (variety, fertilization, and soil and crop management) applied in combination was double that of the sum of the increases due to the same three steps applied singly, thus illustrating the large synergistic effect when all three steps were applied together in a system (Fig 5). It was also noted that there was a slight synergistic effect when any two factors were combined; however, the magnitude of this effect was far less than that of the three-factor combination.

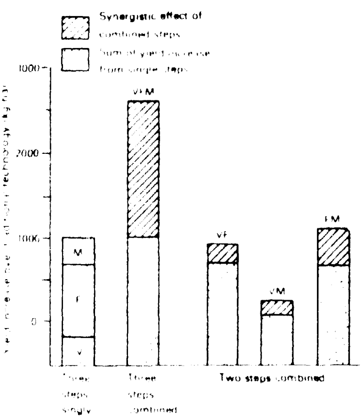

Figure 5. Sorghum grain yield increases from improved variety (V), fertilization (F), and soil and crop management (M) singly and in combination over traditional technology, 1976.

Similar results were obtained on a Vertisol with maize in 1976 and sorghum in 1977 (Table 5). Synergistic effects were observed in maize yields in North Carolina (Krantz and Chandler 1954) and in wheat yields in India (Krantz et al. 1975) when all major factors were combined in a production system. From the data in Table 5 it is apparent that the greatest treatment effects upon yield are found with cereals in which the improved varieties have had a far greater breeding effort than in the grain legumes. This is reflected in the greater responsiveness of the cereals to improved fertilization and management. The sum of the increase for improved variety, fertilization and management applied singly is Rs 2660/ha, and the value for these three factors combined is Rs 3870/ha, which reflects a strong synergistic effect for combining the three factors. The largest proportion of the synergistic effect is due to the increase from improved management over traditional management at improved levels of variety and fertilization (treatments 7 and 8).

Five cm of water applied to the pigeonpea in 1976 and to chickpea in 1977 resulted in an average increase of Rs. 550/ha or Rs. 11 000/ha meter of water.

Broadened Research Approach Needed

There is an urgency to increase and stabilize food production in the semi arid tropics where there is undependable rainfall, the recent population explosion, repeated food crises, and the rapid expansion of cultivated land into more erodible areas causing degradation of the soil-resource base.

Table 5. Effects of traditional[a] and improved[b] levels of four steps in improved technology upon maize/pigeonpea intercrop in 1976–77, sorghum/chickpea sequential crop grain yield (kg/ha) in 1977–78, and mean gross annual value (Rs/ha) for the 2 years on a medium-deep Vertisol.

Treatment no	Variety	Fertility	Soil and crop management	Supplemental water	1976–77 intercrop		1977–78 seq crop		2-year[c]
					Maize	Pigeonpea	Sorghum	Chickpea	Mean value
1	Trad	Trad	Trad	0	450	320	1110	169	1020
2	Trad	Trad	Imp	0	660	614	1370	185	1490
3	Trad	Imp	Trad	0	1900	452	1670	129	1890
4	Trad	Imp	Imp	0	2610	572	2090	291	2620
5	Imp	Trad	Trad	0	630	499	2950	479	2340
6	Imp	Trad	Imp	0	960	639	3570	596	2970
7	Imp	Imp	Trad	0	2220	540	4800	557	3770
8	Imp	Imp	Imp	0	3470	604	5840	708	4890
9	Trad	Imp	Imp	5[d]	2610	728	2090	660	3180
10	Imp	Imp	Imp	5[d]	3470	837	5840	987	5440
LSD	(0.05)					470	218	440	179

a Trad = Traditional system. Varieties—maize, short duration local, pigeonpea, local, sorghum, PJ8K; chickpea, local. Fertilization—10 tons/ha farmyard manure in 1976 and none in 1977. Soil and crop management simulates the present traditional farmer practice with bullocks and desi implements; fertilizer broadcast and seed sown with 3-row desi drill (called Tipponi 30 cm between rows; 3 rows of maize to 1 row of pigeonpea; one insecticide application on pulses only.

b Imp = Improved technology. Varieties — maize SB23, pigeonpea, ICRISAT 1, sorghum, CSH 6, chickpea, local. Fertilization—75 kg/ha 18–46–0 plus 67 kg/ha N topdressed. Soil and crop management—all tillage, planting, and cultivation with improved animal-drawn implements. Fertilizers banded and seed sown with one row of pigeonpea in center of ridge and one row of maize 45 cms to each side on broad (150-cm) beds, sorghum three rows and chickpeas four rows/150 cm bed. One insecticide application on pulses only.

c Market price (per 100 kg) Maize — traditional, Rs 85; SB23, Rs 83, Pigeonpea — traditional, Rs 190; ICRISAT 1, Rs 210; sorghum, local Rs 61; CSH 6, Rs 68; chickpea — both local, Rs 225, value of fodder not included.

d No water applied to maize intercrop, pigeonpea main crop, or sorghum crop. 5 cms of supplemental water was applied at harvest of pigeonpea for the ratoon crop in 1976 and at flowering time on chickpeas in 1977.

Therefore any improved variety, cropping system, or new management innovation should be tested in combination with other parts of the farming system on an operational scale to uncover problems and constraints and find opportunities for solution of these problems. Often in experimental stations researchers have shown yield advantages of 20, 40, or even 60% from intercropping, but, due to operational problems and unresearched constraints, this information is ignored, and sole cropping is practiced because of a lack of operational research and extension effort. This emphasizes the importance of working out the operational problems for various intercropping or sequential cropping systems before making recommendations to the extension service agents and to farmers.

With the possibilities of increased yield of cereal food grains such as sorghum and millet, the farmer will need to devote less of his land to grow food grain for himself and the community. This would release the land from food grain production to provide opportunities for more cash crops and livestock feed. This possibility for diversification should increase stability and profitability for farmers. However, farmer adoption can be made more feasible if the associated land management and cropping systems possibilities are researched on an operational scale to develop alternative, economically viable farming systems.