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TECHNOLOGIES OF SEED-COTTON PRODUCTION IN A PROGRESSIVE AREA OF THE PUNJAB*

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Micro components of alternative technologies of seed-cotton production were identified and estimated through a multistage cross sectional survey. It was found that not only the factor proportions but also techniques and practices of the three classes of farms (by productivity) differd significantly. The low-yield farmers could increase productivity per acre four times by using factor proportions, techniques and practices of the high-yield farmers. Additional cost of this transition will be about six hundred rupees per acre provided supply and access constraints are removed.

INTRODUCTION

Analytically, a study of ranges of technological and technique choice is important for evolving a strategy of crop development that aims at improving income and employment opportunities of farmers in Pakistan. Many technological alternatives are possible and there is a wide scope for substitution between factors of production and between techniques. Seed cotton is a cash crop, its products and by-products satisfy intermediate and final demands in the national and international markets. Thus, indirectly, income and employment opportunities in the related markets and industries would be affected by actual technologies and techniques employed by farmers in the production of this crop.

The production of the crop may be represented by a time phased process comprising sub-processes, each of which required making and carrying out organizational and operational decisions on time and effectively. These decisions are manifested in factor proportions used by firms to produce a given output.

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In the recent past, empirical work on crop production economics has taken a detour from its preoccupation with the development and testing of optimization models that stood on the necessary and sufficient conditions, to a detailed indentification of alternative field technologies of crop production and constraints faced by farmers in the adoption of production recommendations.

This study went along this detour and identified microcomponents of each of the sub-process under conventional (lowyield), transitional (intermediate yield) and progressive (high yield) systems of the crop operations' management.

Broadly speaking, the aim of the study was to identify technologies and techniques adopted by cotton producers showing different levels of productive efficiency. Specifically, however, three hypotheses were tested; (a) the use of factor inputs differs significantly between a given combination of performance groups of farms, (b) the plant density is correlated with the productivity and differs significantly across technologies and (c) the improved methods are associated with the productivity.

METHODOLOGY : SAMPLE AND SURVEY DESIGN

The study is based on a sample survey of 61 respondents selected from four villages located at 4-7 miles distance from Depalpur. Data were collected in four visits to the field at different times during the crop season of 1979-80. Date collection activities were phased in time keeping in view operations of the crop.*

RESULTS AND DISCUSSION

This section deals with the productive efficiency, plant density, seed-bed preparation, planting cost, interculture and thinning techniques, labour input, chemical fertilizer, pest management and benefit-cost analysis of transition from LYF and INTYF to HYF.

The Productivee Efficiency

The mean yields per acre for the three classes of farms are compared in table 2. As compared to the LYF, the HYF and the INTYF obtained 356 and 123 per cent high yields, respectively. Thus, the magnitude of the realizable potential was quite high under farmers' field conditions. From the t- test, it

* For an elaborate discussion of the survey design see Aslam (3).

was infered that the differences in mean yields between any combination of two farm classes (out of three) were significant at P≤0.05. The plot of human labour and operating capital used to produce a unit of output resulted in a distinct scatter of points for each class of farms. A free-hand Unit-Efficiency Isoquant (5) curve was fitted. In figure 1, firms located on the curve were the most efficient, technically speaking. The ratio of distances OA/OB is a measure of firm B's relative efficiency. As expected, the LYF were located the highest in the input space.

A passing reference to capital-output and labour-output ratios seems in order here. An indomitable fact emerged from the data in table 1 that the HYF used the highest doses of the operating capital and human labour per acre and achieved the highest efficiency in their use per quintal. As compared to the LYF, they (the HYF) used one-half of the capital and one-third of the labour for producting a quintal of cotton.

Table 1 *Labour-output and Capital-output Ratios of Cotton*

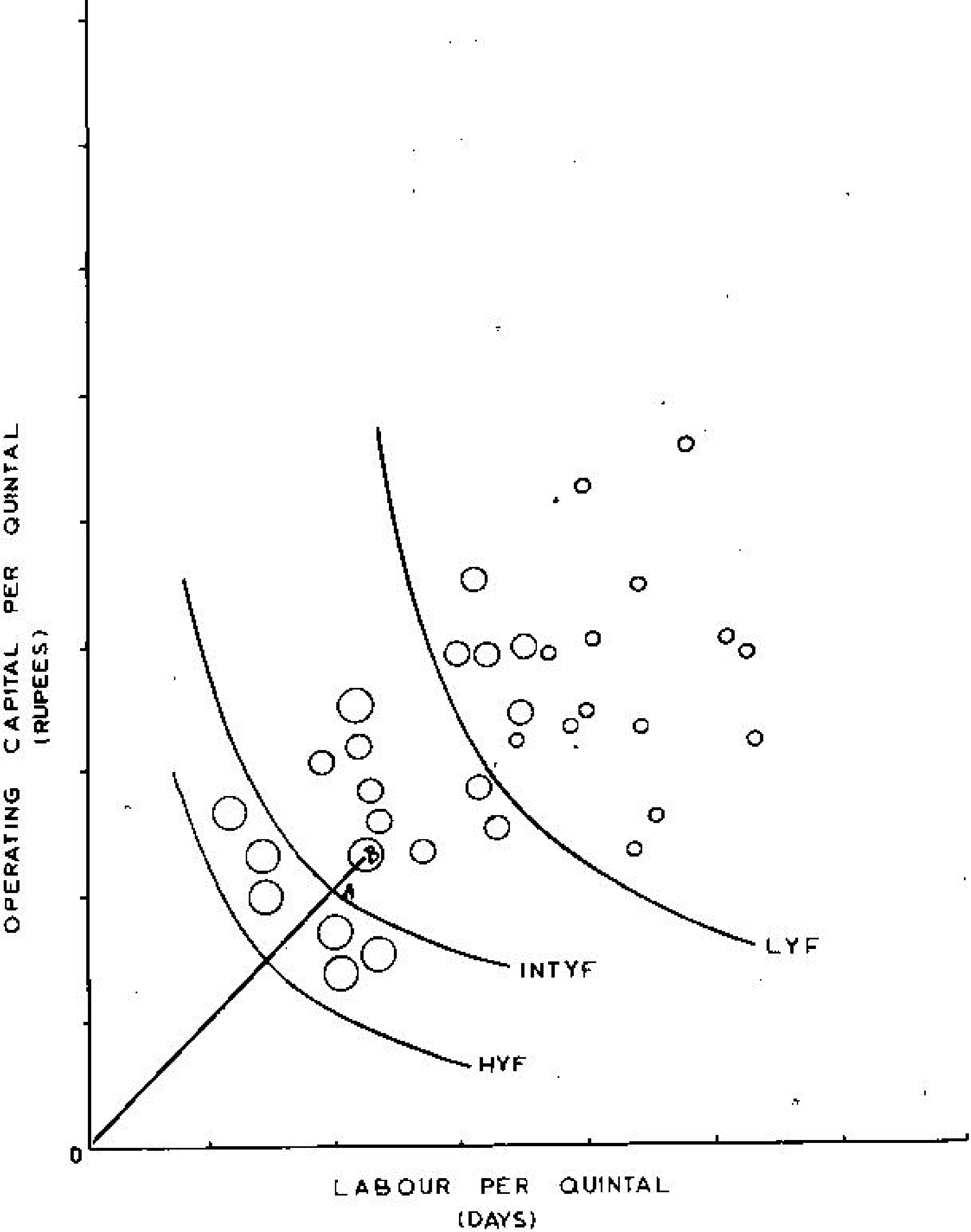
Yield Class	Operating Capital* (Rupees)		Human Labour (Days)	
	Per quintal	Per acre	Per quintal	Per acre
HYF (n =16)	117.8	879.0	5.6	42.0
INTYF (n =24)	156.5	567.0	9.5	34.3
LYF (n =21)	206.4	331.8	18.0	29.0
All farms (n = 61)	126.7	742.9	6.6	38.6

*not inclusive of fixed capital service flow.

An explanation might be that all firms have potential access to the same technology, but some are more successful than others in exploiting it partly due

FIGURE 1

FREE-HAND ESTIMATE OF UNIT-EFFICIENCY ISOQUANT OF COTTON



to an easy and quick access to farm power, labour and water resources. In a developing agriculture, multiple constraints may cause farmers to have actual access only to a small part of the full technological set.

Plant Density

Theoretically, the plant density is determined by many factors some of which required sophisticated experiments to measure them. However, it was postulated that the plant density would depend on seed source, delinting of seed, seed rate, method of sowing, seed-bed dose of fertilizer, interculture and crust-formation and its breaking. Data on these variables are presented in table 2. Apart from other details, a few significant facts are;

a) Almost a three-fourth majority of the HYF used improved seed and followed improved techniques such as chemical delinting of seed and line-sowing in addition to intensive interculture by three techniques.

b) As compared to the other two farm classes, the HYF used the highest seed rate and doses of fertilizer per acre. A unique component of the technology was the use of 11 kilograms of potash per acre.

c) Moving down to the other two classes, it may be seen that the relative frequency of respondents using improved techniques and methods declined.

d) As compared to the LYF, the HYF and the INTYF had 31 and 22 per cent higher plant density. The plant density was, however, remarkably lower than the lower bound of the recommended range; i. e., ≥ 20 thousand plants per acre. The actual plant density was one-half, two-third and seven-tenth of this bound in case of the LYF, the INTYF and the HYF respectively. Farmers reported many constraints— -most significant being poor quality of seed, its asymmetrical distribution over space and time and shortage of labour and small-scale (low-cost) machinery for line-sowing. Further, high plant density encouraged a high weed and pest population. Thus the plant density would peak to the extent the farmer could manage and control weeds and pests. Poor management capability of the farmer in conjunction with an uneven distribution of services of weed and pest control mach-

FIGURE 2

A[illegible] DENSITY AND YIELD PER ACRE OF COTTON

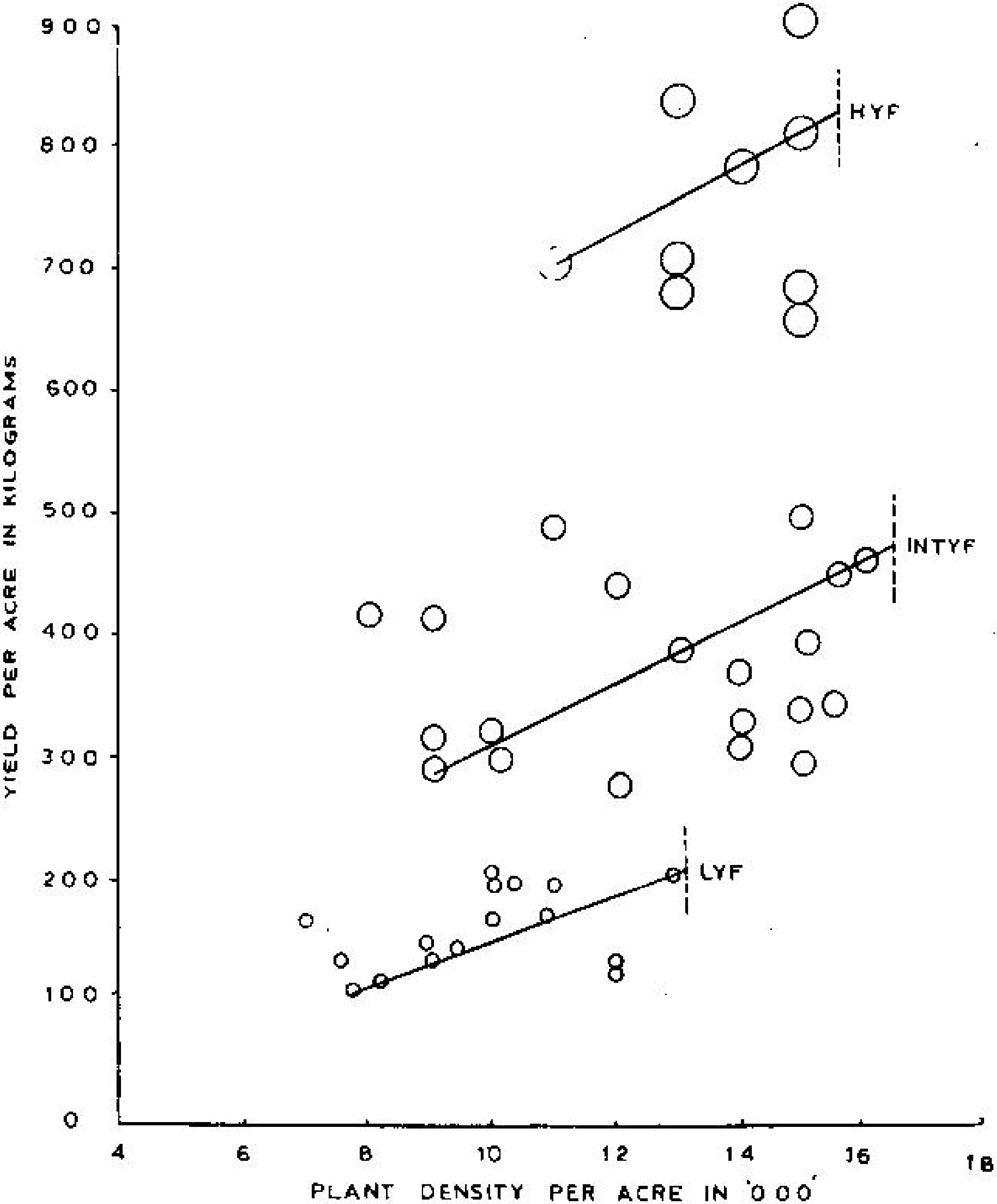


Table 2 *A Comparative Scenario of Plantig Technology, Techniques, Plant Density and Yield Per Acre of Cotton*

Yield Class	Seed Source (n)		Delinting of seed (n)			Seed rate (Kilograms)	Method of sowing (n)		Fertilizers Seed-bed dose (Nutrient Kilograms)			Interculture frequency per acre			Plant density in '000'	Yield (Kilograms)
	Improved	Unimproved	A	B	None		1	2	N	P	K	Png	Hng	Tng		
HYF	13	3	12	4	0	8.2	12	4	21.4	25.1	11.0	3	1	2	14.0	733.1
	(81)	(19)	(75)	(25)			(75)	(25)								
INTYF	17	7	13	10	1	7.3	13	11	18.4	18.4	0	2	1	1	13.1	358.7
	(71)	(29)	(54)	(42)	(4)		(54)	(46)								
LYF	15	6	5	16	0	6.0	3	18	11.9	12.2	0	2	1	0	10.7	160.8
	(71)	(29)	(24)	(76)			(14)	(86)								
All farms	45	16	30	30	1	7.8	28	33	19.7	22.1	7.0	2	1	1	12.6	578.9
	(71)	(26)	(49)	(49)	(2)		(46)	(54)								

Note: n = number of observations. A and B stand for chemical and physical method of delinting seed, respectively. Under the method of sowing, 1 stands for line-sowing by drill and 2 for broadcast. N = Nitrogen, P = Phosphorus and K = Potash. Only 3 farmers used K. Png: Ploughings, Hng: Hoeings and Tng: Thinnings. Figures in parentheses are percentages. For a given combination of farm classes (out of three) mean seed rate, plant density and seed-bed dose of fertilizer were significantly different at $P \leqslant 0.10$. Alternatively, the hypotheses of equality of seed rate and plant density were rejected. The difference in the mean yields of users of improved seed was significant at $P \leqslant 0.10$. Further, the hypothesis that the two methods of sowing resulted in equal mean yields was also rejected at $P \leqslant 0.05$. As expected, it was infered from Chi-square tests that the method of sowing and source of seed were associated with the levels of productivity.

Table 3. *Means of Plant Density, Seed Rate, Fertilizers and Yield Per Acre*

Yield Class	Plant Density: Intervals in '000'	Plant Density: Mean in '000'	Seed rate (Kilo-grams)	Fertilizers, Seed-bed dose: Nitrogen (Nutrient Kilograms)	Fertilizers, Seed-bed dose: Phosphorus (Nutrient Kilograms)	Fertilizers, Seed-bed dose: Potash (Nutrient Kilograms)	Yield (Kilograms)
	7 – ⩽10	10.0	4.2	11.5	11.5	0	690.7
HYF	>10 – ⩽13	12.5	7.0	16.9	16.9	23.1	733.4
(n_1 = 16)	>13 – ⩽16	14.7	7.3	23.2	28.4	6.7	687.6
	>16	17.5	5.6	11.5	11.5	0	561.3
	7 – ⩽10	9.2	5.4	13.8	13.8	0	337.4
INTYF	>10 – ⩽13	12.0	6.7	22.3	22.3	0	374.0
(n_2 = 24)	>13 – ⩽16	15.0	7.5	17.7	17.7	0	383.2
	>16	19.0	7.6	24.3	24.3	0	282.9
	7 – ⩽10	9.0	5.8	10.7	10.7	0	154.9
LYF	>10 – ⩽13	12.1	5.8	13.5	13.5	0	171.5
(n_3 = 21)	>16	17.0	5.6	11.5	11.5	0	104.5
	7 – ⩽10	9.1	5.6	11.8	11.8	0	246.0
All farms	>10 – 13	12.1	6.3	17.7	17.7	11.5	352.6
(n = 61)	>13 – 16	14.9	7.4	[illegible]	25.3	4.8	521.6
	>16	17.8	6.2	13.9	13.9	0	37.2

inery and equipment over space and time, limited supply of liquidity to transact their services and seasonal shortage of labour constrained plant density.

It was observed that those who experienced crust-formation also broke it. Only three farmers (5 per cent) reported reseeding.

The evidence indicated that (a) variability in th plant density was related with the variation in physical inputs and techniques and (b) plant density, cetris paribus, was related with the productivity. Hence, the case for programmes and policies, intended to increase plant density, is obviously strong and compelling.

An interval classification of plant density, seed rate, fertilizer dose and yield per acre may be perused in Table 3. It is interesting to note that, regardless of the class, at the plant density of 16 thousand, the yield decreased. This is not too difficult to interpret. It may be seen that at farms having > 16 thousand plant density, fertilizer use was high and in two out of the three classes, seed rate was also high. Further, it is logical to expect that they might have used more than normal delta of water. These three factors in comb nation with the resultant plant density, increase chances of heavy infestation by weeds and insect pests which, if uncontrolled, would slash the yield considerably.

Seed-bed Preparation

The germination of the crop, initial weed control and irrigation application efficiency would depend, in a large measure, on the preparation of the seed bed. It requires ploughing, planking and levelling practices that are carried out one or more times by a number of techniques depending on the type of farm power and machinery actually available to a given farmer and the real cost of hiring their services in the market. The relevant data are exhibited in Table 4. For ploughing, the use of tractor was fairly common in each class. However, for planking and levelling, majority of the LYF used bullock power. The recommended depth of sowing was not practised by many of the LYF and the INTYF and fields were not precisely levelled and, therefore, the germination was adversely affected. Differences in actual access and use of tractor services (lag in service acquisition, number of times acquired, hours of use each

Table 4. *Operations of Seed-bed Preparation for Cotton*

Operations	Source of Energy	Range of Operations	Number of Observations			All Farms	
			HYF	INTYF	LYF	n	Per cent
		1-3	1	2	0	3	4.9
	Tractor	4-5	7	8	7	22	36.1
		>5	5	8	2	15	24.6
Ploughings	Bullock	4-5	1	1	6	8	13.1
	Tractor-	4-5	1	5	4	10	16.4
	Bullock	>5	1	0	2	3	4.9
		1-3	9	11	5	25	41.0
	Tractor	4-5	3	6	1	10	16.4
Planking	Bullock	1-3	2	4	12	18	29.5
	Tractor-	4-5	2	1	2	5	8.2
	Bullock	1-3	0	2	1	3	4.9
	Tractor	Once	8	6	0	14	23.0
Land	Bullock	Once	4	9	10	23	37.7
levelling	None		4	9	11	24	39.3

time, type of share used, type of field and mode and rate of payment for the service) by farmers (intending to supplement conventional seed-bed preparation technique with that of tractor) reflected on the quality of the seed-bed prepared. Is it possible to regulate the tractor-hiring market such that it delivers a uniform and standardized service to the hiring farm? Yes, in this regard, the extension service and local institutions of farmers have a useful role to play.

Planting Cost

The variable costs of planting cotton were identified to be those of seed-bed preparation, manuring, seed and its delinting and fertilizer. The irrigation cost was assumed constant. Data (Table 5) showed that, regardless of the class, seed-bed preparation accounted for nearly 50 per cent of the total planting cost. The fertilizer and seed costs were the highest on the HYF and, as expected, manuring cost was the highest on the LYF. In total, the HYF incurred 35 per cent more expenditure on planting than the LYF. The significant components that manifested wide variation across the classes were seed and fertilizer.

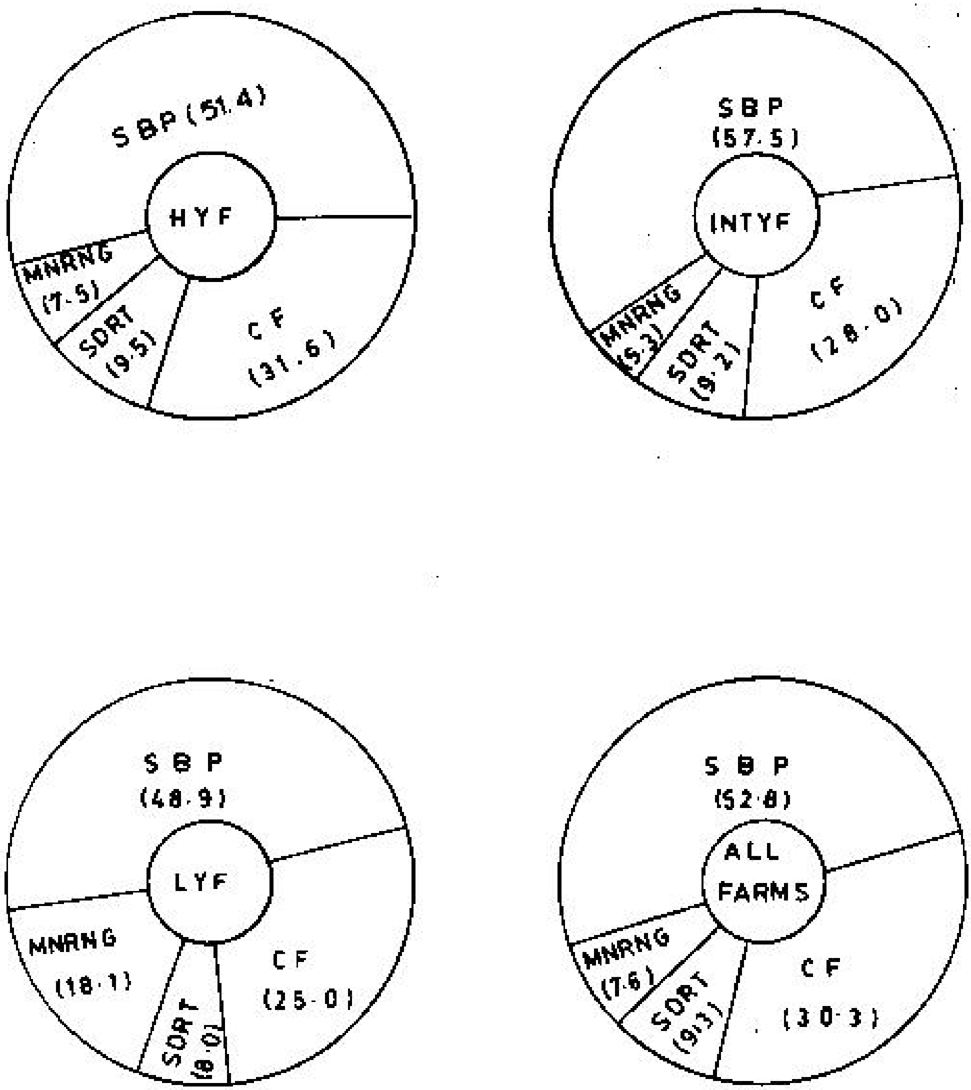
Table 5. *Variable Costs of Planting Cotton Per Acre (In Rupees)*

Yield Class	Components				Total
	Seed-bed preparation	Manuring	Seed	Chemical fertilizers	
HYF	152.1	22.2	28.3	93.5	296.1
(n_1 = 16)	(51.4)	(7.5)	(9.5)	(31.6)	(100)
INTYF	161.9	14.8	26.0	79.0	281.7
(n = 24)	(57.5)	(5.3)	(9.2)	(28.0)	(100)
LYF	107.6	39.7	17.6	54.9	219.8
(n_3 = 21)	(48.9)	(18.1)	(8.0)	(25.0)	(100)
All farms	151.0	21.6	26.7	86.5	285.8
(n = 61)	(52.8)	(7.6)	(9.3)	(30.3)	(100)

Note : Seed-bed preparation included ploughing, planking and levelling. The fertilizer cost is for seed-bed dose only.

FIGURE 3

PLANTING COST PER ACRE OF COTTON



NOTE: SBP; SEED-BED PREPARATION, MNRNG; MANURING, SDRT; SEED RATE AND ITS DELINTING AND CF; CHEMICAL FERTILIZERS.

Interculture and Thinning Techniques

The operation-level data gave strength to this study as the detailing of the range of techniques in each operation enabled us to draw contours of the range of the production processes of cotton. A part of the production process was represented by interculture and/or thinning operations as exhibited in Table 6. As expected, majority of the HYF had high levels of interculture by the three techniques. The HYF also did thinning meticulously. The high rate of improved seed in combination with high doses of fertilizer, as pointed out already, propagated weed population which, if uncontrolled, would constrain severely the realization of incremental output due to fertilizer. Obviously, high-yield technology generated demand for additional input of labour and specialized machinery. If the demand for labour is not matched by a corresponding change in the supply (family or hired labour), the incremental output would, undoubtedly, be lower than its potential. The complementary nature of the relationship between high dose of fertilizer and labour cannot be over-emphasized.

Table 6. *Interculture and Thinning operations of Cotton*

Yield Class	Operation Techniques with Levels									
	Ploughing			Hoeing			Thinnig			
	0	1-3	4	0	1-2	3	0	1	2	4
	(Number of observations)									
HYF (n_1 = 16	0	9	7	3	12	1	3	1	12	0
INTYF (n_2 = 24)	1	20	3	4	20	0	11	2	9	2
LYF (n_3 = 21)	1	20	0	1	20	0	18	0	3	0
All farms (n = 61)	2 (3.3)	49 (80.3)	10 (16.4)	8 (13.1)	52 (85.2)	1 (1.7)	32 (52.4)	3 (5.0)	24 (39.3)	2 (3.3)

Note : Ploughing and hoeing have three levels. Thinning has four levels

Labour Input

Human labour input per unit of area under the crop depended on the technology of production, techniques followed in the execution of practices, extent of adoption of the recommendation domain and the level of yield obtained (labour needed for picking of cotton). As compared to the LYF, the HYF used more of physical inputs, followed a larger number of recommendations and realized greater yield per acre, hence, it was logical to observe that they used about 45 per cent more labour. The variation in the labour use across farm classes was explained by the labour-intensity of interculture and picking operations. The use of labour in sowing and other operations was almost the same for the three classes. A relatively low use of labour in land preparation on the HYF was understandable for they used mechanical power which required low complementing input of labour. The difference in mean labour use of small and large farms was non-significant at $P \leq 0.05$. The reason was the use of labour-saving sources of power (tractor) by a number of small farmers as well. The high-yield technology was found to be more labour-intensive as compared to the other two technologies as this technology necessitated the performance of labour-intensive operations (ploughing, hoeing and/or thinning for weed control and uniform stand of the crop). This result comared well with that of Shapiro (10) who demonstrated that management was labour-augmenting in cotton production in Tanzania.

The shortage of the time of family labour or its employment in other economic and social jobs, differences in the real wage rate from farm to farm or village to village, health and nutritional status, living environment and alternative employment conditions of rural landless labour might constrain the adoption of recommendations that involved intensive use of human labour. An encouragement of inter-regional migration of labour and an improvement of health, nutrition and general living conditions of rural labour may help relax these constraints in the long run. Further, the need for the development of operation-specific and small-scale farm machinery which will reduce the tedium of farm labour while increasing its productivity is too obvious to emphasize.

Table 7. *Technical Coefficients of Human Labour in Cotton Production*

Yield Class	Farm Size	Operation Domain					Total	
		Land preparation	Sowing	Inter-culture	Picking	Others	Per acre	Per quintal
		(In	days	per	acre)			
	Small	1.4	0.5	4.9	40.4	5.1	52.3	7.5
HYF	Large	0.7	0.5	6.7	28.0	5.9	41.8	5.6
($n_1 = 16$)	Both	0.7	0.5	6.6	28.3	5.9	42.0	5.6
	Small	1.2	0.5	3.1	23.8	5.7	34.3	9.4
INTYF	Large	1.1	0.6	4.9	22.2	5.3	34.1	9.5
($n_2 = 24$)	Both	1.1	0.6	4.7	22.4	5.4	34.2	9.5
	Small	1.7	0.6	3.3	17.8	3.9	27.3	16.5
LYF	Large	1.7	0.7	3.8	18.0	5.7	29.9	18.9
($n_3 = 21$)	Both	1.7	0.6	3.6	17.9	5.1	28.9	18.0
	Small	1.5	0.6	3.6	25.2	4.8	35.7	9.9
All farms	Large	0.9	0.5	6.0	25.8	5.7	38.9	6.4
($n = 61$)	Both	0.9	0.5	5.8	25.7	5.7	38.6	6.6

Note : Land preparation includes tilling, planking and levelling operations. Sowing includes the operations of (i) making ridges for field partitioning and (ii) sowing either by broadcast or by drilling in furrows. Others cover the operations of manuring, water application and spraying. Interculture encompasses ploughing, hoeing and thinning.

Chemical Fertilizer

The fertilizer is an energy-intensive input* and became more expensive (in real and nominal terms) in the seventies. An efficient use of fertilizer, therefore, assumed paramount importance.

Assuming that the insect attack was insignificant, the potential incremental output due to fertilizer will be realized if (a) the quantity applied was within the reach of roots of the plants (not in the empty space between plants), (b) weeds were controlled effectively, (c) dose and type were related not only with deficiencies in the soil, but also with the stages of plant growth and maturity, (d) water stress is minimal and (e) plant density is adequate and uniform. To the extent these, rather stringent, conditions were not met with, the output response would be constrained and the actual output would be lower than its potential. During actual observation of the fields it was found that the situation about these conditions was far from satisfactory on the INTYF and LYF, that is, plant density was low, weed population was high, the fertilizer dose and type deviated from the recommendation and, above all, fertilizer was broad-cast by hand resulting in its uneven distribution and inefficient use. The recommendation of applying fertilizer by 'pore' (long funnel) in the plant-bed could not be followed as 54 per cent of the respondent did not sow in lines. It is noteworthy that, in a given set of critical operations, the succeeding operation will be efficient if the relevant preceding operation was also efficient. A failure to understand the complementary relationship of the operations might also act as a binding constraint.

With high doses of fertilizer, infestation of weeds becomes worse and, hence, the need for weeding more frequently and intensively. An additional demand for labour is created. Moreover, high dose of fertilizer is associated with heavy pest infestation since the dense and genetically uniform stands (from improved variety) provide a more favourable environment for pests. The high-yield technology brought in its wake the demand for (a) pesticides, sprayers and pest management knowledge and (b) an additional demand for labour. The

*Energy is needed not only for its production; but also for the production of the fertilizer plant and the distribution of the fertilizer.

Table 8. *Doses of Chemical Fertilizers*

Yield Class	Farm Size	(Nutrient Kilograms Per Acre)					Nutrient Kilograms Per Quintal	
		Seed-bed dose		Flowering time dose	Total			
		N	P	N	N	P	N	P
	Small	12.6	18.2	41.1	53.7	18.2	8.0	2.7
HYF	Large	21.6	25.3	33.9	55.6	25.3	7.6	3.4
(n_1 = 16)	Both	21.4	25.1	34.1	55.5	25.1	7.6	3.4
	Small	14.0	14.0	25.5	39.5	14.0	10.9	3.9
INTYF	Large	18.9	18.9	38.1	57.0	18.9	15.7	5.2
(n_2 = 24)	Both	18.4	18.4	36.9	55.3	18.4	15.3	5.1
	Small	14.5	15.2	23.0	37.5	15.2	23.8	9.6
LYF	Large	10.4	10.4	24.8	35.2	10.4	22.3	6.6
(n_3 = 21)	Both	11.9	12.2	24.1	36.1	12.2	22.8	7.7
	Small	13.9	15.5	28.1	42.0	15.5	12.0	4.4
All farms	Large	20.2	22.7	34.5	54.8	22.7	9.2	3.8
(n = 61)	Both	19.7	22.1	34.0	53.7	22.1	9.3	3.8

Note : N and P stand for nitrogen and phosphorus, respectively. The null hypothesis of equality of means of N used by HYF and LYF was rejected at $P \leq 0.05$. The similar hypothesis for phosphorus was also rejected at $P \leq 0.1$.

dependency of one element of the high-yield technology on the other is conspicuous by its absence.

The quantities of fertilizers used are shown in table 8. The notable facts were (a) only three of the HYF used potash at the sowing time and the average for the three came to 11 kilograms, (b) the seed bed dose of the LYF was around one-half of the dose given by the HYF and (c) flowering-time dose of N of the LYF was about two-third of corresponding dose of the HYF. In total, the HYF used 54 per cent more of N and 105 per cent more of P as compared to the LYF. It seemed that, in addition to the management factors, input variability was also responsible for varition in yield per acre. The results were in agreement with Staub (11) who showed that in switching over to high-yield technology, volume and number of applications of chemical fertilizer increased greatly. On the basis of a quintal of cotton per kilogram of N, the HYF were three times more efficient than LYF and on the basis of a quintal of cotton per kilogram of P they were twice more efficient than the LYF. The nature, type, intensity and timing of operations and practices were responsible for the high efficiency.

A detour might be taken to examine bank credit to support purchase of inputs such as fertilizer. In the recent years, the supply of credit has been increased manifold and, to a limit, its nominal price is zero, i.e., it is free of interest. Further, to expand the demand for credit, the supply of a limited amount of short term credit has been unmoored from cultivator's equity. Though the policy encouraged the use of loan money by farmers, it is mistake to assume that all farmers in need of the credit in kind would take it even with zero price and no collateral. The reason is that the demand for the credit is derived from the production function which is constrained by many technical factors. To the extent the production is bounded by these constraints, the risk of borrowing will be increased via failure to repay. To use loan to buy fertilizer and apply it in the field does not guarantee realization of incremental output due to fertilizer. A host of other operations and practices constitute the necessary condition for securing the incremental output. The constraints make the the demand for capital in kind so inelastic that incresing its supply alone is not sufficient to cause substantial increase in the specific use of capital by farmers with very limited management capability. The risk can certainly be reduced if management services are provided with the credit. The study showed that management and capital are highly complementary resources and, therefore, there is a strong case for a tie-in of management services and credit, of couse, in the strict sense of Supervised Credit. The proposition that management is a more limitational resource than capital in Pakistan's agriculture provides another basis for this tie-in.

Pest Management

Three avenues are open to overcome the pests; (a) develop resistance to it, that is, improvement of genetics make-up of the plant, (b) develop means to destroy it, that is, biological and chemical control and (c) develop means to live with it, that is, destruction of alternate host and timely operations of weeding and interculture. As farmers did not possess the capability to exploit the first alternative, they used chemical and management methods for the control of insect pests in cotton. Having discussed the weeding and interculture operations, let us look at chemical means of insect pest control.

The frequency distribution of farms according to number of sprays, times of sprays and cost per acre and quintal are evinced in Table 9. To begin with, it is important to know as to how many did not spray at all ? To which yield class did they belong ? Out of 61 cases, 17 (28 per cent) did not spray at the early stage, 12 (70 per cent) of them were the LYF and 5 (30 per cent) were the INTYF. Further, 12 (20 per cent) farmers did not spray at all at the flowering stage, 11 (92 per cent) of them were the LYF and only 1 (8 per cent) was the INTYF. Slightly more than half of the LYF did not spray at all at any stage. As against this, all of the HYF sprayed the crop. The number of sprays of the most efficient farmers ranged between 8-10. The cost of spraying of the HYF was about eight times higher than that of the LYF. The cost per quintal was low on the INTYF and LYF due to arithmetic illusion of computing cost per quintal from a very low total cost as compared to the HYF. Be it noted that the complementarity of high doses of fertilizers with insect infestation necessitated the HYF to incur high costs on plant protection by chemical means.

Table 9. *Pest Management Operations and Costs of Cotton*

Yield Class	Farm Size	Number of Observations						Cost	
		Early Stage Number of sprays			September onward Number of sprays			Per acre	Per quintal
		0	1-2	3-4	0	1-3	4-6	(Rs.)	(Rs.)
	Small	0	5	—	0	4	1	153.8	22.2
HYF	Large	0	7	4	0	1	10	313.4	41.9
$(n_1 = 16)$	Both	0	12	4	0	5	11	309.0	41.4
			(75)	(25)		(31.2)	(68.8)		
	Small	4	7	0	1	10	0	101.3	27.9
INTYF	Large	1	12	0	0	12	1	81.4	22.5
$(n_2 = 24)$	Both	5	19	0	1	22	1	83.3	23.0
		(20.8)	(79.2)		(4.2)	(91.6)	(4.2)		
	Small	5	7	0	5	7	0	63.3	38.2
LYF	Large	7	2	0	6	3	0	28.6	17.7
$(n_3 = 21)$	Both	12	9	0	11	10	0	40.5	25.2
		(57.1)	(42.4)		(52.4)	(47.6)			
	Small	9	19	0	6	21	1	98.0	27.2
All farms	Large	8	21	4	6	16	11	231.8	38.3
(n = 61)	Both	17	40	4	12	37	12	221.6	37.8
		(27.9)	(65.6)	(6.5)	(19.7)	(60.6)	(19.7)		

Note : Figures in parentheses are percentages.

Table 10. *Factor Coefficients of HYF and LYF*

Factors (per acre)	HYF 1	LYF 2	Factors differences 1-2
Seed (Kilograms)	9.2	5.7	3.5
Seed delinting (Rs.)	3.2	1.3	1.9
Chemical fertilizers			
N	55.5	36.7	18.8
P	25.6	12.4	13.2
K	11.2	—	11.2
Yard manure in cart-loads	2.0	2.0	—0.1
Pest management			
Number of sprays	8.0	1.0	7
Capital cost (Rs.)	309.0	40.5	268.5
Farm power in hours			
Bullock	0.6	14.9	—14.3
Tractor	5.1	1.3	3.8
Manual labour in days			
Family labour	1.8	10.2	—8.4
Casual hired labour	32.2	17.4	14.8
Permanent hired labour	8.0	1.4	6.6
Total labour	42.0	29.0	13.0
Tubewell water (acre inches)	12.9	13.5	—0.6
Interculture in number			
Ploughing	3	2	1
Hoeing	1	1	0
Thinning	2	0	2

Note : N: Nitrogen, P: Phosphorus and K: Potash. Fertilizers were measured in nutrient kilograms. Pest management capital cost includesexpenditure on pesticides, hired labour and machinery.

From LYF and INTYF to HYF

Assuming that the relevant constraints are eliminated, what it takes to transform the LYF to the HYF? The answer to this question is given in Table 10, where additional quantities of factors are listed. A cursory look at the table would reveal that improved seed, fertilizers, plant production, farm power and casual hired labour would constitute the main resource needs. The benefit-cost ratio of moving from the LYF to the HYF and from the INTYF to the HYF may be seen in table below:

Table 11. *Benefit-cost Ratios in the Transformations*

Particulars	From LYF to HYF	From INTYF to HYF
VC*	611.4	381.0
NI-I*	2010.7	1441.0
Benefit-cost ratio	3.3	3.8

*See in appendix.

This meant that an additional rupee expenditure on the variable factors of production would fetch a net return of Rs. 3.0 – 3.8 provided constraints were removed. This result came close to the oft-quoted claim that the unexploited field potential of the crop was 300 – 400 per cent of the actual (6).

Some Correlation Tests

Theoretically and intuitively, it is possible to relate relevant factors of production with total production but a given set of empirical evidence may not permit rejection of the hypothesis that correlation coefficient of the population is significantly different from zero. Or, contrary to expectations, empirical evidence may exhibit weak relationships. This is likely to be true in the case of cotton production in Pakistan. The reason is that during the period between planting and picking, the plant is exposed to many factors (nature, environment, clima-

Table 12. *Correlation Matrix of Critical Variables in Cotton Production*

Variables	SD /A 1	NPKS /A 2	TNPK /A 3	SEDP /A 4	L/A 5	L/Q 6	K/A 7	K/Q 8	PD /A 9	EPP /A 10	TP /A 11	TC /A 12	NI-1 /A 13	MS 14	PFS 15
1. SD/A	1	.27	.32	.10	.24	−.32	.42	−.13	.39	.24	.33	.40	.32	.43	.38
2. NPKS/A	...	...1	.89	.10	.23	−.10	.49	.17	.18	.30	.22	.42	.33	.29	.40
3. TNPK/A	...	...	1	.09	.33	−.24	.59	.14	.33	.32	.30	.52	.27	.36	.43
4. SEDP/A	...	...	...	... 1	−.03	−.02	.37	.18	.21	.2	.09	.27	.03	.23	.28
5. L/A	...	...	...	...	... 1	−.40	.52	−.37	.40	.46	.71	.55	.67	.52	.43
6. L/Q	...	...	...	...	...	1	−.40	.69	−.36	−.47	−.60	−.48	−.79	−.41	−.41
7. K/A	...	...	...	...	...	...	1	.05	.50	.77	.67	.88	.54	.64	.69
8. K/Q	...	...	...	...	...	...	...	1	.01	−.09	−.50	.00	−.60	−.14	−.16
9. PD/A	...	...	...	...	...	...	...	...	1	.43	.45	.49	.38	.63	.29
10. EPP/A	...	...	...	...	...	...	...	...	...	1	.70	.70	.62	.46	.53
11. TP/A	...	...	...	...	...	...	...	...	..	...	1	.64	.96	.55	.57
12. TC/A	...	...	...	...	...	...	...	...	...	...	...	1	.49	.57	.59
13. NI-1/A	...	...	...	...	...	...	...	...	...	...	...	...	1	.52	.52
14. MS	...	...	..	...	...	...	...	...	...	...	...	...	...	1	.50
15. PFS	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1

Note : SD; Seed, NPKS; nutrient kilograms of nitrogen, phosphotus and potash applied at sowing time, TNPK; total nutrient kilograms of nitrogen, phosphorus and potash, SBDP; seed-bed prepartaion, L; human labour, K; operaring capital, PD; plant density, EPP; expenditure on plant protection, TP; total product, TC; total cost, see Aslam (3) for NI-1, TC, MS; Management score and PFS; Profile score, /A: per acre and/Q: per quintal.

te, etc.) that affect the productivity adversely meaning thereby that if a farmer fails to carry out one critical operation on time and effectively (and is successful in doing other operations), the productivity may decline. For example, high labour use will bring forth high productivity only if plants are protected from insect damage or high plant density will result in high productivity only if weed control and interculture practices are followed in addition to other critical operations. Another example may be that heavy doses of human labour (seed-bed preparation and interculture) will not secure high productivity if seed is poor in quality and plant density is low. These illustrative examples provide an understanding as to why some of the correlation coefficients in Table 12 were weaker than expected. A selected set of nine correlation coefficients were subjected to a test of the null hypothesis that each one of them was equal to zero. In each case, the null hypothesis was rejected.

Table 13. *Tests of Significance of Selected Correlation Coefficients*

1.	SD/A	vs.	PE/A	... ...	0.39*
2.	PD/A	vs.	TP/A	... ...	0.45*
3.	L/A	vs.	TP/A	... ...	0.71*
4.	K/A	vs.	TP/A	... ...	0.67*
5.	L/Q	vs.	TP/A	... ...	−0.80*
6.	K/A	vs.	TP/A	... ...	−0.50*
7.	EPP/A	vs.	TP/A	... ...	0.70*
8.	MS	vs.	TP/A	... ...	0.55*
9.	PFS	vs.	TP/A	... ...	0.57*

Note : vs: Versus.

*Correlation coefficient significantly different from zero at $P \leq 0.05$.

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Appendix : Definitions and Measurements

1.	HYF	High yield farms; i.e., >522.0 kilograms (>14 'maunds') of seed-cotton per acre.
2.	INTYF	Intermediate yield farms; i.e., >261.0 – ⩽522.0 kilograms (>7.0– – ⩽14.0 'maunds') of seed-cotton per acre.
3.	LYF	Low yield farms; i.e., 0 – ⩽261.0 kilograms (0 – 7 ⩽ 'maunds') of seed-cotton per acre.
4.	Farm size	A farm was classified small if its cultivated area was ⩽14.0 acres and large, otherwise.
5.	Land	It was measured in acres.
6.	Human labour	This is the summation of family, permanent and casual hired labour and exchange labour used in the crop production and was measured in days.
7.	Seed	The seed included the quantity reseeded. The seed was considered improved if its sources were Pakistan Agricultural Development Supplies Corporation and Progressive Farms subject to the qualification that the farmer, having used it, testified its quality. The home produced seed, under progressive management conditions, was also placed in the category. The seed was classified unimproved, otherwise. Obviously, the strict definition of improved seed was not adhered to.
8.	Operating capital	Money value of seed, fertilizers, tubewell water, tractor ploughing and sprays used in the production of the crop. These items were evaluated at the prevailing market price or at the opportunity cost, as was the case.
9.	Plant protection cost	This is a summation of costs of pesticides and labour and machinery hired for this prupose.
10.	Plant density	The plant density was measured in number of plants per acre. For decription of the methods of measurement see (7) or Aslam (3).
11.	NI – 1	The gross income minus expenses on variable factors or production (seed-bed preparation and interculture, seed and its delinting, yard manure, chemical fertilizers, pest management, tubewell water and casual hired labour).