PN-AAL-284

Economics Program
Progress Report 25

An Analysis of Levels, Patterns and Determinants of Fertilizer Use on Farms in Selected Regions of Semi-Arid Tropical India

Dayanatha Jha and Rakesh Sarin

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
ICRISAT Patancheru P.O.
Andhra Pradesh 502 324, India

October 1981

AN ANALYSIS OF LEVELS, PATTERNS AND DETERMINANTS OF FERTILIZER USE ON FARMS IN SELECTED REGIONS OF SEMI-ARID TROPICAL INDIA

Dayanatha Jha and Rakesh Sarin*

Several studies have indicated that irrigation, area under commercial crops and spread of fertilizer responsive high yielding varieties of cereals, have been the main determinants of fertilizer consumption levels in India (Desai and Singh 1973, Jayaraman 1979, Jha and Sarin 1980). These broad tendencies arise from decisions taken by individual farmers. As such, proper understanding of the observed patterns of fertilizer use can emerge only by studying the behavior of these individuals. It is important to undertake such a study because it is at this level that responses to policy, investment and technological interventions actually take place. Knowledge about these responses and constraints operating at farm level, in turn, shape new policies and provide guidelines for designing more appropriate institutional and technological strategies. This paper, therefore, focuses attention on fertilizer use patterns and practices observed on farms in selected regions of SAT India.[1]

Fertilizer use decisions are complex. To start with, the farmer has to decide whether or not to use fertilizers. Then follow decisions of which crop(s) to fertilize and at what rate(s). Capital rationing and other factors often necessitate decisions on how much crop area to fertilize. This set of decisions leads to the observed pattern of fertilizer consumption. Very few studies in this country have analyzed these patterns in depth (Desai 1969, Desai et al., 1973, Maharaja 1975) and still fewer have focused specifically on studying the determinants of these decisions (NCAER 1974).

Equally important from the point of view of technical efficiency of fertilizer use, are decisions regarding how to use fertilizers. Factors such as choice of fertilizer material, method and timing of fertilizer application, balanced use of different plant nutrients, integrating organic and inorganic sources of plant nutrients, etc., are important in this context and factual information on these aspects could provide useful guidance to extension efforts.

---

*Economics Program, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh 502 324, India. J.G. Ryan, H.P. Binswanger, and M. von Oppen have gone through earlier versions of this report. We are grateful for their comments. The authors acknowledge the assistance rendered by Sri. E. Jagadeesh throughout the course of this study.

1. We have used the acronym SAT to denote semi-arid tropics throughout the text.

This study attempts to provide information on these aspects based on comprehensive village studies data pertaining to three important agro-climatic zones of SAT India. The specific issues presented relate to:

1. Adoption of fertilizers
2. Average level of fertilizer use
3. Allocation of fertilizers
4. Rates of application and extent of fertilizer use
5. Agronomic management of fertilizers
6. Use of organic manures

These aspects are covered in the first part of this paper. The second part presents an analysis of determinants of fertilizer use. This is a regression-based analysis which hypothesizes that fertilizer use decisions are influenced by a set of personal, resource endowment, institutional and agroclimatic factors. The analysis has been carried out at two levels — one emphasizing inter-farm variability in fertilizer use and the other concerned with understanding, in addition to the above, the influence of some plot level characteristics as well.

The next section describes the data source and a brief background of the study areas. Section III presents data on the status of fertilizer use and the following section deals with the analysis of determinants of fertilizer use. The last section summarizes the results and highlights some important conclusions.

II. DATA SOURCE AND BACKGROUND OF THE STUDY AREAS

Data for this analysis come from ICRISAT Village Level Studies being conducted in six villages[2] — two each in three major agroclimatic zones of peninsular India, since 1975. In each of these villages, data from 40 households (10 each from landless labor, small, medium and large farm categories) have been intensively monitored by resident investigators. Salient agroclimatic and farm resource endowment features of the selected villages are presented in Appendix I.

Region I (Sholapur) is characterized by low and unstable rainfall and is dominated by postrainy season cropping of mainly coarse cereals and pulses on medium-deep Vertisols. Region II (Akola) has similar soils, stable and somewhat higher rainfall, very little irrigation and fairly high area under nonirrigated commercial crops. Region III (Mahbubnagar)

---

2. For details, see Binswanger, Jodha, Ryan, von Oppen 1977.

has red soils, high irrigation intensity, low rainfall and relatively smaller holding size. The cropping pattern is dominated by paddy.

For this study only those sample (farmer) households were selected for which data were available continuously for three years (1975-76 through 1977-78). There were 146 such households — 49 in Region I, 52 in Region II and 45 in Region III. Data on cropping patterns, fertilizer use and other relevant aspects for these households were retrieved from original schedules for all the three years. In addition, special surveys were conducted in these villages during 1979 and 1980 to elicit data on initial adoption of fertilizers by farmers, their knowledge regarding recommended fertilization practices, constraints inhibiting fertilizer use, farmers' opinion regarding response of different unirrigated crops to fertilizer application and related aspects.

All the results in the subsequent sections have been presented region-wise for Regions I and II. For Region III, in view of the substantial difference in irrigation availability between Aurepalle and Dokur villages, estimates for both the villages have been given separately. The four situations — Sholapur, Akola, Aurepalle and Dokur, represent a spectrum of contrasts within the SAT environment: Sholapur and Dokur depicting extreme situations.

All estimates presented in this section are based on three-year averages. Because of sampling problems we have not analyzed the data size-groupwise. This aspect is covered in the regression based analysis given in the next section which also considers inter-year variations. In all tables fertilizer quantities have been expressed in terms of nutrients — N, P_2O_5 and K_2O after appropriate conversions.

Most of the earlier micro-level studies on fertilizer use (Desai 1969, Desai et al. 1973, NCAER 1974, Maharaja 1975, NCAER 1978) have been able to provide only a partial view of the different dimensions of fertilizer use, mainly because of data inadequacies. We hope that analysis of the comprehensive ICRISAT Village Level Studies data would lead to better understanding of the fertilization practices of farmers in the selected regions.

III. FERTILIZER USE ON FARMS

1. Adoption of Fertilizers

The first overt indicator of acceptance of an innovation is its adoption. As such, information on the overall level of adoption provides an idea regarding the extent to which fertilizer use has been integrated in a given farming system. Table 1 provides data on the average proportion of sample farmers using fertilizers during 1975-78.

Table 1. Proportion of farmers using fertilizers in different regions (1975-78)

Particulars	Sholapur	Akola	Mahbubnagar	
			Aurepalle	Dokur
Percentage farmers using fertilizers[a]	29	43	38	80
Percentage users among:				
Small farmers	14	17	0	79
Medium farmers	37	45	24	50
Large farmers	32	65	83	96
Percentage users in:				
1975-76	31	40	33	67
1976-77	31	43	41	83
1977-78	24	47	41	89

[a]Calculated by aggregating total number of farmers using fertilizer irrespective of whether they have been different or same farmers over the period of three years, expressed as percentage of the total number of farmers in these three years.

The first row of the table shows that adoption of fertilizers was lowest in Sholapur and highest in Dokur: Akola and Aurepalle occupying intermediate positions. The table also revealed higher adoption on large farms as compared to small farms in all regions. These findings indicated that superior production environment (in the regional context) and higher socioeconomic status (in the inter-farm context) contributed towards higher adoption. In Dokur the level of adoption was quite high even on small farms. Interestingly, differences in irrigation availability did not appear to be important in explaining inter-farm size differences in adoption levels. With the exception of Aurepalle, in all other villages the percent irrigable area was higher on small farms (Jodha et al. 1977).

Inter-year variation in the proportion of fertilizer users showed that excepting Sholapur, the proportion was rising in other areas — Dokur showing the most impressive gains. The exception of Sholapur emphasized the sepcial nature of this region.

In order to explore the adoption pattern further, some additional data were collected from the sample farmers in 1979 and 1980 on when the farmer started using fertilizers and on which crop. The results have been summarized in Figure 1 and Table 2.

Figure 1 shows that fertilizer use was a relatively recent practice in Sholapur and Akola regions. None of the sample farmers in these regions had used any fertilizer before 1964. In Akola, there was rapid increase in adoption since then but in Sholapur the pace has not been as fast. Of the two villages in Mahbubnagar region, more than half the farmers had taken to fertilizers before 1959 in Dokur and by 1978 everyone had used fertilizers: in Aurepalle fertilizer use started in the early sixties but the cumulative percentage of fertilizer users did not rise above 55% by 1978. Thus, one notes fertilizer use to be an established practice in the highly irrigated Dokur village. In Akola, adoption was late but the pace has been very rapid since then. In the low rainfall regions with little irrigation — Sholapur and Aurepalle, the overall adoption as well as its diffusion over time has been poor.

In Table 2, information is provided on crops which were fertilized at the time of initial adoption. In both Aurepalle and Dokur, fertilizer use started on paddy. In the former, some farmers also started with hybrid sorghum. In these two villages fertilizer use started well before the advent of the high yielding varieties in the mid-sixties. Fertilizer use started in Akola with hybrid sorghum and cotton crops. Thus in both these regions, availability of irrigation and/or high response crops prompted adoption of fertilizers. Similar pattern was observed in a study in Guntur region (Desai _et al_. 1973).

In Sholapur region, in contrast to others where one or two crops dominated as the initially fertilized crops, farmers started with a more diverse crop basket. Some started with irrigated crops like paddy, wheat, maize, vegetables or sugarcane, others chose the high response nonirrigated crops like hybrid sorghum or groundnut.[3] While the basic forces (irrigation and high response) appeared to be similar, the Sholapur situation suggested a longer phase of experimentation by farmers. This phenomenon was also observed in another low rainfall SAT district — Bellary (Karnataka), where fertilizer use is a recent practice (Krishnaswamy and Patel 1973).

---

3. Even for these unirrigated crops, post-rainy season cropping implied assured soil moisture for adequate crop growth (Jodha 1979).

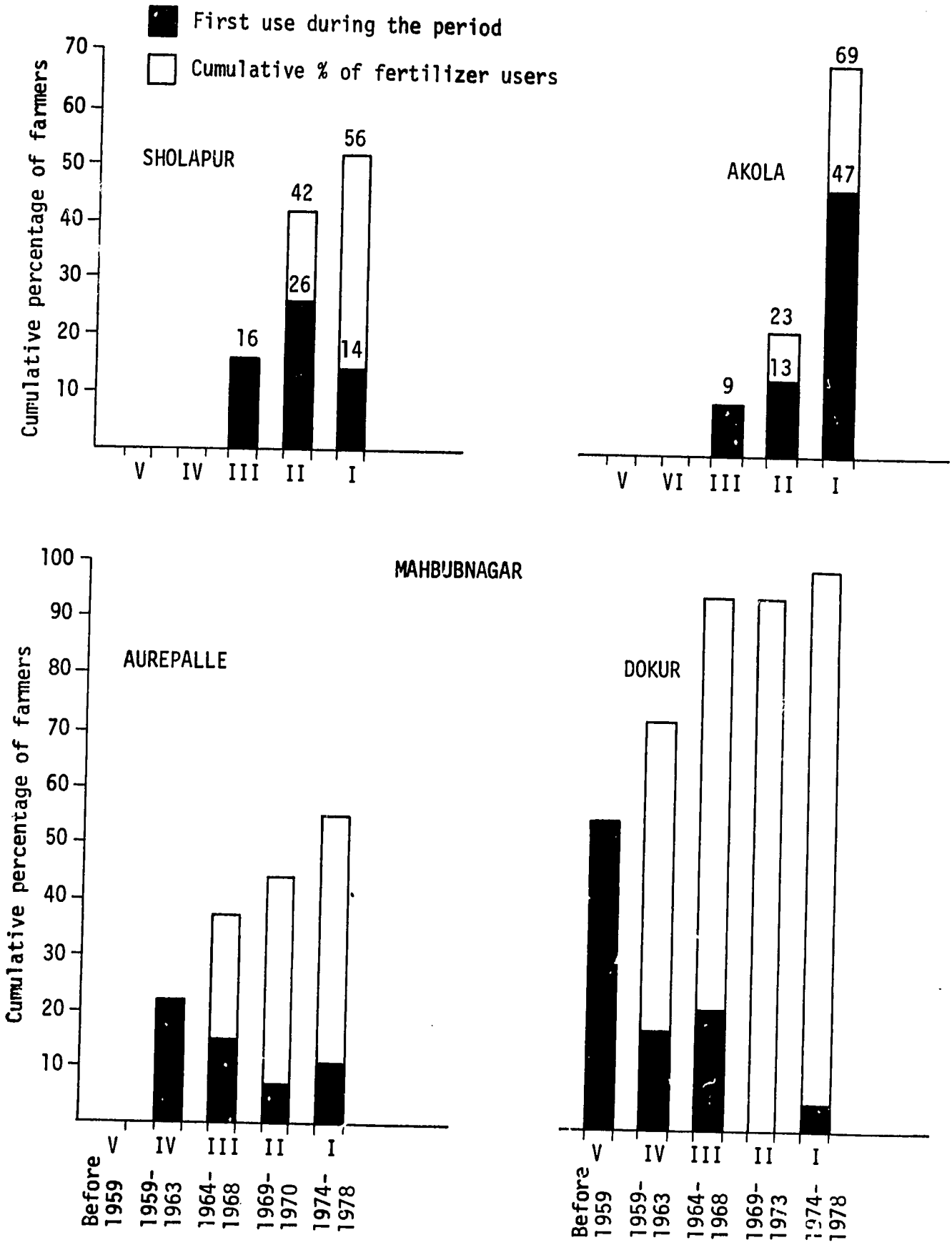


FIGURE 1. ADOPTION OF FERTILIZER OVER TIME IN SHOLAPUR, AKOLA AND MAHBUB-NAGAR REGIONS.

Table 2. Distribution of sample farmers according to crops on which fertilizer was first used.

Crop	Sholapur	Akola	Mahbubnagar	
			Aurepalle	Dokur
Hybrid sorghum	17	62	13	0
Paddy	17	2	87	100
Wheat	17	7	0	0
Cotton	0	29	0	0
Groundnut	11	0	0	0
Vegetables	17	0	0	0
Others	21[a]	0	0	0
Total	100	100	100	100

[a]Includes maize (11%), sugarcane (6%), others (4%).

The above picture is based on adoption, irrespective of continuity in use of fertilizers. Scrutiny of data for each farmer revealed that adoption was not a one time decision for all farmers. Table 3 shows the distribution of fertilizer users over the three-years period[4] in different categories.

The first two rows of the table show the percentage of continuous users and the third row shows new adopters in 1977-78. In Dokur, 94% of the fertilizer users belonged to the consistent users' category, only 35% of the users in Sholapur fell in this class. The last category included farmers who used fertilizers in some year(s) but not in others. Nearly half of the fertilizer users in Sholapur belonged to this category.

4. Three years are not enough for an analysis of this type but the point we want to make, comes out quite clearly even with these data.

Table 3. Distribution of fertilizer users according to pattern of use over 1975-78.

User category	Sholapur	Akola	Mahbubnagar	
			Aurepalle	Dokur
Users in all 3 years	26	65	57	69
Users in last 2 years	9	8	8	25
Users in last year	17	10	14	0
Others	48	17	21	6
Total	100	100	100	100

Finally, an attempt was made to ascertain reasons for non-adoption of fertilizers. Table 4 lists the three most important reasons put forward by non-users in four villages. It is clear from the table that lack of awareness or apprehensions about the profitability of fertilizer use did not figure as an important reason for non-use of fertilizers. In almost all cases, irrigation and lack of capital were mentioned as the most important reasons. Riskiness was also mentioned as an important reason. Under nonirrigated conditions and with inadequate capital, it is logical for farmers to be concerned about risk. In Akola and Aurepalle 94 and 41% of farmers respectively reported fertilizer use on nonirrigated crops. It was in these areas that risk was mentioned as a deterrent factor. In Dokur and Sholapur few farmers ever used fertilizer on nonirrigated crops and therefore appreciation of the role of this factor was not overtly expressed. The comprehensive NCAER fertilizer demand survey and some other studies also emphasized irrigation and credit as the most important constraints in widespread adoption of fertilizers (Maharaja 1975, NCAER 1978).

Fertilizer use is a well-established practice in the irrigated SAT areas (Desai and Singh 1973, Desai et al. 1973, Jha 1980). In areas having relatively high and stable rainfall and substantial area under high-value, high response crops, its use appears to have started in the mid-sixties and has grown rather rapidly since then. Low rainfall, nonirrigated SAT regions, on the other hand, have low adoption levels and considerable year to year variation in the proportion of farmers using fertilizers.

2. Profile of Fertilizer Use

This section gives a brief overview of the average levels of use of chemical fertilizer in the selected regions. Table 5 shows the average application rates and extent of area fertilized with different nutrients.

Table 4. Reasons for non-use of fertilizers.

District/Village	Reasons for non-use		
	1st reason	2nd reason	3rd reason
Sholapur (Shirapur)	Irrigation	Credit	Availability
Akola (Kanzara)	Irrigation	Credit	Risk
Mahbubnagar (Aurepalle)	Irrigation	Credit	Risk
Mahbubnagar (Dokur)	Irrigation	Credit	--

Table 5. Average level of chemical fertilizer use on farms in different regions (1975-78).

Particulars		Sholapur	Akola	Mahbubnagar	
				Aurepalle	Dokur
Average level of ($N+P_2O_5+K_2O$) use per ha of gross cropped area (kg)		2	7	12	39
Average rate of application per fertilized ha (kg):	N	28	25	53	62
	P_2O_5	17	13	27	34
	K_2O	17	8	12	16
Percentage gross cropped area fertilized (%) with:	N	5	18	17	45
	P_2O_5	2	13	10	23
	K_2O	2	12	3	21

The overall fertilizer use intensity indicated by the average level of fertilizer ($N+P_2O_5+K_2O$) use was found to be very low in almost all regions except in Dokur where the average level came to about 40 kg per hectare. These figures emphasized low levels of as well as high inter-regional variability in fertilizer use in SAT areas. The table also shows that these low levels arose mainly from very poor extent of fertilization. Only a nominal fraction of the cropped area was fertilized in Sholapur; in Akola and Aurepalle also, the percentage area fertilized with nitrogen

did not exceed one-fifth of the cropped area. Even in the highly irrigated Dokur village all the irrigated land did not receive fertilizers.

It is important to note that in all the regions adoption levels (Table 1) were significantly higher than the percentage areas fertilized, despite the fact that farmers have been using fertilizers for 10 years or more. This lag has two important meanings. Firstly, it indicates low diffusion of fertilizers (even in highly irrigated areas). Secondly, it suggests that from the point of view of fertilizer promotion, alternative strategies may be required to raise the levels of these two determinants.

The actual rates of application (Table 5) were found to be nearly twice as high in Mahbubnagar as compared to Sholapur and Akola regions. Akola and Aurepalle provide an interesting comparison because the crop area fertilized was about the same in both but the rates (for N and P_2O_5 particularly) were markedly different.

Interregional variability in the average parameters needs to be explained. A detailed analysis follows in the next section; in Table 6 we provide data on the influence of irrigation on fertilizer use.

Table 6. Irrigation and fertilizer use (1975-78).

District/ Village	% crop area irri- gated	% of total fertilizers ($N+P_2O_5+K_2O$) used for irrigated crops	% of total fertilized area (with N) irrigated	Rate per fertilized hectare (kg)					
				Irrigated			Nonirrigated		
				N	P_2O_5	K_2O	N	P_2O_5	K_2O
Sholapur	10-13	75	55	39	23	23	14	11	11
Akola	4-5	37	15	65	32	18	18	10	6
Mahbubnagar									
Aurepalle	21	97	91	60	32	14	14	10	2
Dokur	60	99	98	63	34	16	16	19	16

The table shows quite clearly that irrigation played a dominant role in Sholapur and Mahbubnagar regions. Fertilizer use in these regions was restricted to irrigated crops only which accounted for 75 to 99% of the total fertilizer used. The Akola region, which had relatively higher rainfall provided an interesting contrast. This region had meager irrigation (less than 5%), yet more than one-third of the total fertilizers was used on irrigated crops. However, bulk of the fertilizer was used on non-irrigated crops which accounted for 85% of the total fertilized area. These data indicated that fertilizer use in the low rainfall areas of the SAT was confined to irrigated lands only. In relatively higher (and more stable) rainfall areas, on the other hand, fertilizer use was quite common under rainfed conditions.

The rates of fertilization under irrigated conditions were remarkably similar in Akola and Mahbubnagar regions (60-65 kg N, 32-34 kg P_2O_5 and 14-18 kg K_2O per fertilized hectare). The rates for nonirrigated crops were also quite comparable across regions. The exceptional case of Sholapur (irrigated rates) needs to be noted. On the whole, it is interesting to note that almost the entire variability in rate of fertilizer application across regions can be explained by the irrigation factor alone.

Table 7 which contains data on the percentage of irrigated land receiving different nutrients highlights an important aspect of fertilizer use on irrigated lands.

Table 7. Proportion of irrigated area receiving different plant nutrients in different regions.

District/Village	Percentage irrigated area receiving		
	Nitrogenous fertilizers	Phosphatic fertilizers	Potassic fertilizers
Sholapur	34	13	12
Akola	41	31	31
Mahbubnagar			
Aurepalle	81	46	16
Dokur	68	34	31

The table reveals that even though most of the fertilizer was used on irrigated lands, a significant proportion of such lands did not receive any fertilizers. In Mahbubnagar villages, 20 to 30% of the irrigated area remained unfertilized; in the Maharashtra districts, nearly 60% of the irrigated area was unfertilized. While lack of capital and/or nonavailability of fertilizers could be responsible for this situation in Sholapur and Mahbubnagar, the Akola case was puzzling because a large part of fertilizer was used for nonirrigated crops in this area. The existence of a fair proportion of unfertilized irrigated land was also revealed by other data sources (Jha 1980). Exploitation of this slack could lead to significant productivity gains in SAT agriculture.[5] It also follows that amelioration of constraints will result, at least in Sholapur and Mahbubnagar situations, in extension of fertilizer use first on hitherto unfertilized irrigated lands.

5. Such an effort is already underway under the Intensive Fertilizer Promotion Campaign in selected districts having assured irrigation but low fertilizer consumption levels (Sohbati 1979).

3. Allocation of Fertilizers

A number of studies have revealed that farmers' choice of crops to be fertilized is influenced by the relative profitability of responses to fertilizer application (Desai 1969, Desai et al. 1973, Maharaja 1975). The dominance of irrigated crops (in low rainfall situation) shown earlier provides partial evidence in support of this trend. The theme is pursued further and attention is focused on allocation of fertilizers among crops. The above tendency would imply that relatively more fertilizer responsive crops would claim a larger share in the total fertilizer used on farms. Table 8 provides data on cropwise allocation of fertilizers ($N+P_2O_5+K_2O$) in different regions.

In the Mahbubnagar villages, high yielding varieties of paddy dominated the fertilizer scene overwhelmingly. The only other crops which received some fertilizers were groundnut, vegetables and castor (in Aurepalle). No fertilizer was used for sorghum in either village even though this crop occupied a significant area.

The pattern observed in Sholapur -- another low rainfall region, was interesting. The region is characterized by highly subsistence-oriented cropping pattern — local varieties of sorghum and pulses accounting for nearly 85% of the gross cropped area. In this region crops like sugarcane, vegetables and paddy — grown on only about 5% of the cropped area, accounted for about 60% of the total fertilizers used. In significant contrast to other regions, traditional varieties of sorghum also claimed a significant share. For this crop almost the entire quantity of fertilizers was used in the post-rainy season.

The allocation pattern was more diversified in Akola region. A number of crops were fertilized — important among them were cotton, wheat, sorghum and groundnut. For both wheat and sorghum, the high yielding varieties were preferred. The former occupied only two percent of the gross cropped area but it used nearly one-third of the total quantity of fertilizers.

The overall pattern presented in Table 8 thus supported the view that high response crops claimed priority in farmers' fertilizer allocation decisions. Irrigated high-value cereals (paddy and wheat), commercial crops (cotton and groundnut) and high yielding varieties of sorghum figured prominently in this regard. Such options appeared limited in Sholapur region and farmers did use some fertilizers for the local varieties.[6] In this case also fertilizer use was confined to the more certain post-rainy rather than the kharif season. The high yielding varieties of sorghum did not cover much area in any region and except in Akola, it did not account for a significant share of fertilizers.

Table 9 and Figure 2 show the allocation pattern under irrigated and nonirrigated conditions separately in Akola and Sholapur regions. Estimates have not been presented for Aurepalle and Dokur since fertilizer use under nonirrigated conditions was nominal in these villages (Table 6). These

6. Note, however, that M-35-1, a variety classified as a local variety of sorghum, is an improved variety with good response to fertilizer application.

Table 8. Cropwise allocation of fertilizers ($N+P_2O_5+K_2O$) on farms in selected regions (1975-78).

Crop	Sholapur		Akola		Mahbubnagar			
					Aurupalle		Dokur	
	% of gross cropped area	% of total NPK	% of gross cropped area	% of total NPK	% of gross cropped area	% of total NPK	% of gross cropped area	% of total NPK
Sorghum - Local	59	22	28	3	35	0	13	0
- HYV	a	2	6	16	a	0	a	a
Paddy - Local	3	12	1	3	5	-	3	1
- HYV	0	0	0	0	11	94[c]	43	90
Wheat - Local	2	5	1	0	a	a	a	0
- HYV	a	a	2	30	a	0	0	0
Pulses	25	a	7	1	2	0	3	0
Groundnut	2	4	6	6	1	0	30	8
Castor	0	0	0	0	35	2	0	0
Other oilseeds	2	0	a	0	5	0	0	0
Cotton - Local	a	0	46	27	0	0	0	0
- HYV	0	0	2	12	0	0	0	0
Sugarcane	1	26	a	a	0	0	0	0
Vegetables	1	21	a	1	5	3	1	a
Other crops	5	8[b]	1	a	a	0	6	1
	100	100	100	100	100	100	100	100

a Less than 0.5; b includes maize - 6%; c Total of HYV and local. The HYV account for nearly two-third of the area.

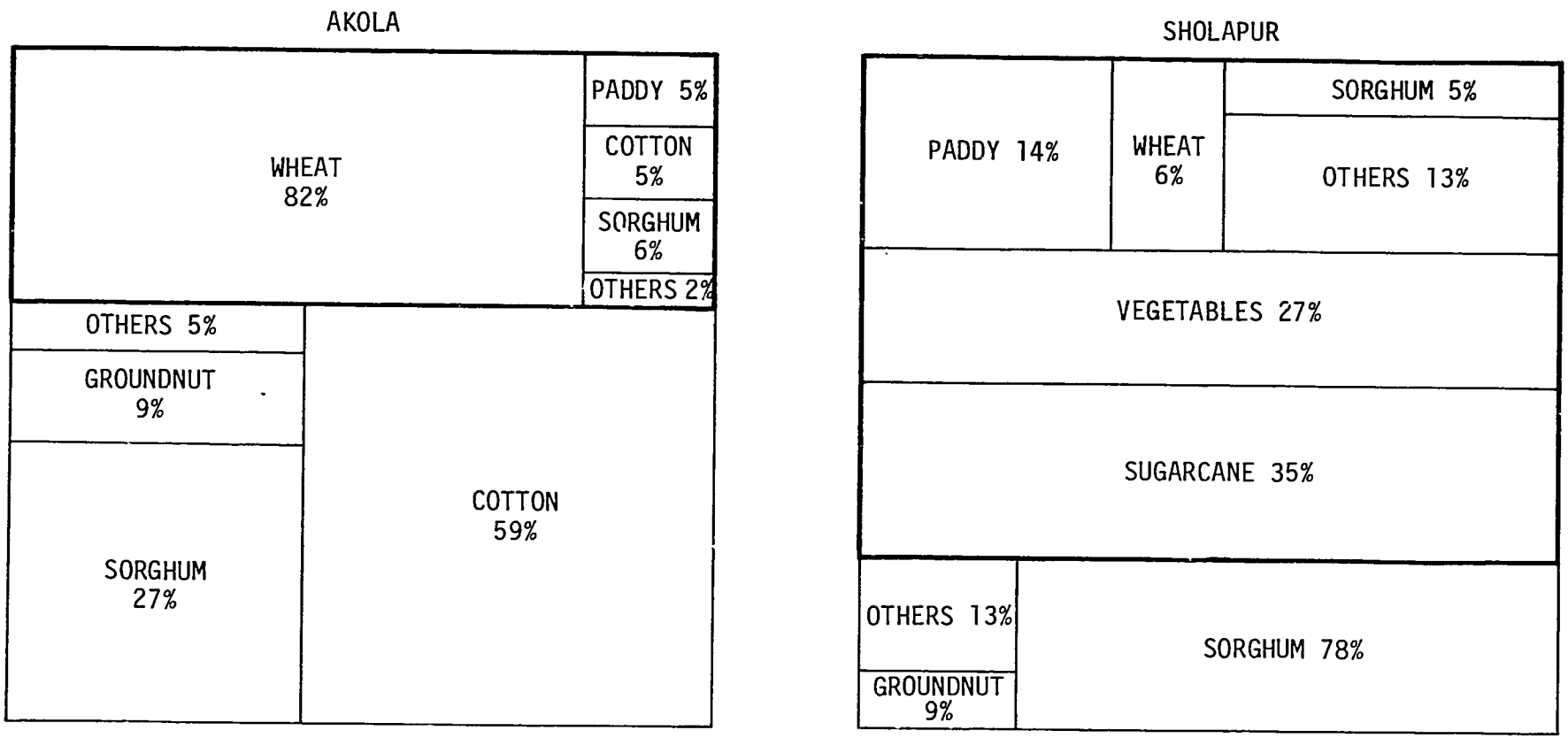
Table 9. Major fertilizer using crops under irrigated and nonirrigated conditions in Sholapur and Akola villages (1975-78).

Crops		Sholapur % of total NPK used on		Akola % of total NPK used on	
		Irrigated crops	Nonirrigated crops	Irrigated crops	Nonirrigated crops
Sorghum	Local	5[b]	72[b]	0	4
	HYV	a	6	6	23
Paddy	Local	14	5	5	2
Wheat	Local	6	2	0	0
	HYV	a	2	82	0
Groundnut		2	7[b]	0	9
Cotton	Local	0	0	0	43
	HYV	0	0	5	16
Sugarcane		35	0	1	0
Vegatables		27	2	a	1
Others		11	4	1	2
		100	100	100	100

a Less than 0.5
b Rabi crop

indicated that crops like sugarcane, paddy, wheat and vegetables accounted for more than 80% of the total fertilizer used under irrigated conditions. Rabi sorghum and rabi groundnut were the main nonirrigated crops fertilized in Sholapur region.[7] Cotton, sorghum (HYV) and groundnut were the important crops in Akola region.

7. The quantity used under nonirrigated conditions was very small.



Sizes of the irrigated and nonirrigated boxes indicate proportions of fertilizer used under these conditions within each district.

FIGURE 2. ALLOCATION OF FERTILIZERS (TOTAL PLANT NUTRIENTS) USED UNDER IRRIGATED AND NONIRRIGATED CONDITIONS IN AKOLA AND SHOLAPUR VILLAGES (1975-76).

These results thus confirmed that both under irrigated and rainfed conditions fertilizer use was concentrated on relatively high response crops. Where such options were limited (as in Sholapur) some fertilizer was used on low-response crops, but in such cases also farmers chose the more stable post-rainy season crop.

The crops consuming bulk of fertilizers currently were the ones on which fertilizer use started initially. This implied that in spite of having used fertilizers for ten years or more, farmers have not extended fertilizer use to other crops and the crop base for fertilizer consumption continues to be narrow. Other nonirrigated (and areawise important) crops like millets, pulses, etc. continue to be grown without fertilizers.

Considerable attention was paid to fertilizer use under rainfed conditions in the supplementary surveys. In all the regions farmers were convinced that under normal circumstances fertilizer use on dry crops (even local varieties) was profitable. It was lack of capital and uncertainty about soil moisture condition which restrained fertilizer use in the low rainfall region (Sholapur and Mahbubnagar). This underscored the importance of institutional credit and of technological innovations (varieties, crop management practices) which minimize the impact of adverse soil moisture conditions during the crop growth period.

4. Rate of Application and Extent of Fertilizer Use

Choice of crops to be fertilized is followed by decisions regarding rates of application and extent of crop area to be fertilized. Table 10 contains data on these aspects for crops which consumed a significant quantity of fertilizer in different regions.

In both the Mahbubnagar villages, more than 80% of the paddy area was fertilized at about 60-70 kg N per fertilized hectare. The areas fertilized with P_2O_5 and K_2O were lower though the rates were similar (33-35 kg P_2O_5 and 15-17 kg K_2O) in the two villages. The areas fertilized and rates for other fertilized crops in these villages (castor in Aurepalle and groundnut in Dokur) were much lower.

In Sholapur, sugarcane and vegetables were fertilized at relatively higher levels. For all other fertilized crops, the rates of application of nitrogen were in the range 17-20 kg per fertilized hectare, the extent of crop area receiving nitrogen was less than 30% (with the marginal exception of paddy). The extent of areas fertilized with P_2O_5 and K_2O were very low. The table shows that only a nominal fraction of the local sorghum area was fertilized — it was only because of the high area under this crop and very low absolute level of fertilizer use in this region that Table 8 showed a high percentage allocation of fertilizers to this crop. It was also interesting to note that the rates of application to local and HYV of sorghum were quite similar; with respect to area fertilized, however, the HYV fared better.

Table 10. Rate of application of nutrients per fertilized hectare in kilograms and extent of area fertilized 1975-78.

Crop		Sholapur			Akola			Mahbubnagar					
								Aurupalle			Dokur		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Sorghum	Local	16.8 (2.5)[a]	11.9 (1.5)	11.9 (1.5)	13.0 (3.2)	4.4 (3.6)	2.6 (3.6)	na	na	na	na	na	na
	HYV	16.7 (28.5)	14.2 (11.2)	14.2 (11.2)	28.5 (45.9)	16.6 (22.8)	10.3 (22.8)	na	na	na	nr	nr	nr
Paddy	Local	20.7 (34.0)	16.5 (9.9)	16.3 (9.1)	43.8 (32.4)	28.6 (12.3)	18.1 (12.3)	nr	nr	nr	nr	nr	nr
	HYV	na	na	na	na	na	na	60.5[b] (82.6)	32.9[b] (47.3)	15.2[b] (13.3)	70.7 (87.0)	34.9 (39.5)	17.1 (34.8)
Wheat	Local	28.5 (11.1)	19.9 (3.1)	19.9 (3.1)	nr	nr	nr	nr	nr	nr	na	na	na
	HYV	nr	nr	nr	76.0 (78.5)	32.5 (65.0)	18.4 (65.0)	na	na	na	na	na	na
Groundnut		24.9 (9.0)	23.2 (2.4)	nr	12.7 (21.7)	11.7 (26.0)	9.9 (15.3)	na	na	na	15.6 (16.4)	31.4 (16.4)	12.6 (16.4)
Castor		na	na	na	na	na	na	6.9 (5.5)	4.6 (4.9)	0.5 (2.1)	na	na	na
Cotton	Local	na	na	na	13.2 (19.5)	7.1 (14.2)	4.6 (13.5)	na	na	na	na	na	na
	HYV	na	na	na	42.3 (79.0)	22.3 (61.3)	14.0 (61.3)	na	na	na	na	na	na
Sugarcane		67.8 (70.9)	35.1 (15.1)	46.9 (15.1)	nr	nr	nr	na	na	na	na	na	na
Vegetables		34.4 (53.6)	31.4 (20.7)	29.8 (20.0)	nr	nr	nr	26.4 (19.3)	10.5 (9.0)	10.5 (9.0)	nr	nr	nr

a Figures in parentheses show the proportions of area under the crop receiving different fertilizers.
na = not applicable; nr = not reported; b = HYV + Local

The fertilizer use values were much higher in the Akola region. For HYV of wheat and cotton, more than three-fourth of the crop area received nitrogenous fertilizers, for phosphorus and potash, the areas fertilized exceeded 60%. In this region, significantly higher fertilizer use parameters were observed for the high yielding as compared to local varieties.

The table revealed that in general both the fertilizer use parameters were higher for irrigated crops. Most of the nonirrigated crop rates (for nitrogen) lay below 30 kg per hectare— HYV of cotton in Akola being an exception.

A more appropriate picture regarding fertilization rates emerges from scrutiny of Table 11 which contains data on recommended levels of fertilizer use for important fertilizer-using crops in different regions.

Table 11. Recommended and actual levels of fertilizer use for selected crops.

Region/Crop/Variety		Recommended levels[a] (kg/ha)			Actual level as % of recommended		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
SHOLAPUR							
Sorghum	Local	25	15	0	67	79	b
Wheat	Local	40	20	0	71	99	b
Groundnut		12	25	0	207	93	b
Sugarcane[c]		250	115	115	27	30	41
AKOLA							
Sorghum	HYV	75	50	40	38	33	26
Wheat	HYV	120	60	60	63	55	30
Cotton	Loca	50	25	0	26	28	b
Cotton	HYV	100	50	50	42	45	28
AUREPALLE							
Paddy	HYV	100	60	0	60	55	b
Castor		40	20	0	17	23	b
DOKUR							
Paddy	HYV	100	60	0	71	58	b
Groundnut		10	30	30	156	105	42

a Source: Field extension workers in different areas.
b No potash recommended.
c Annual crop.

This table clearly revealed that even in the highly irrigated Dokur village, the actual rates of fertilizer application were significantly below the recommended levels. This was true for almost all crops in other regions as well. This is almost universal trend in the country as a whole (NCAER 1978) and the major explanation has been inadequacy of capital and nonavailability of fertilizers.[8] Under these situations lower rates spread over a larger area appears as a reasonable strategy. This finding has an important implication. It has been argued (Desai 1978) that the high fertilizer consuming irrigated areas may soon reach their agronomic potential for fertilizer consumption and therefore cease to generate further growth in effective demand for fertilizers. Our analysis suggests that in terms of rates of application, there is still considerable scope.

The supplementary survey indicated that even in Dokur most of the farmers were not aware of the recommended levels. In other areas, the unawareness was almost total. The NCAER survey also indicated this (NCAER 1978).

Comparison of the two tables also showed that in Mahbubnagar region (and for nonirrigated local varieties in other regions) use of potash was not recommended. Yet one observed use of this nutrient in these situations. This appears to be inefficient. The additional survey revealed that this happened because of availability problems. In most cases farmers had to accept whatever fertilizer (mixtures) were available in the market and in several cases they had to buy mixtures containing potash as well (Umrani 1979). This has important implications in context of fertilizer use efficiency and the working of the fertilizer distribution system.

Going back to Table 10, it was noted that even in the relatively high fertilizer using areas, all the area under the major fertilizer using crops were not fertilized. This was commented upon earlier also (Table 7) in context of the overall data. This has been investigated further in Table 12 which shows the variation in use of nitrogen over years as well as across farm sizes for the most important fertilizer using crops in different regions.

The table shows that in both the Mahbubnagar villages, almost the entire area under HYV of paddy was covered over time. In Akola and Sholapur regions, however, there were considerable inter-year as well as inter-size variations in both rates and area fertilized. This table suggests that in high irrigation and fertilizer using areas, increase in rates of application on irrigated crops and diffusion of fertilizer use on nonirrigated crops would be the main sources of future growth in fertilizer consumption. There

---

8. Risks and lack of profitability of the recommended levels may also be important reasons.

Table 12. Variation in rate of application (per fertilized hectare) and extent of area fertilized with nitrogenous fertilizers for selected crops, over years and farm size.

Region/ Village/ Crop		1975-76		1976-77		1977-78		Small		Medium		Large	
		Rate/ fert. ha(kg)	% area ferti-lized	Rate/ fert. ha(kg)	% area ferti-lized	Rate/ fert. ha(kg)	% area ferti-lized	Rate/ fert. ha(kg)	% area ferti-lized	Rate/ fert. ha(kg)	% area ferti-lized	Rate/ fert. ha(kg)	% area ferti-lized
Sholapur													
Sugarcane		62.5	43.2	60.8	100.0	81.6	52.4	25.9	100.0	58.9	82.1	75.5	65.1
Vegetables		34.2	51.4	16.6	56.6	44.8	53.5	9.1	37.3	47.5	58.4	27.7	53.5
Akola													
Sorghum	HYV	34.5	51.3	29.2	43.3	25.2	45.7	14.0	26.7	21.6	49.5	33.3	48.1
Wheat	HYV	93.8	100.0	77.4	85.9	73.4	65.8	25.3	68.7	66.4	25.8	78.5	96.1
Cotton	HYV	36.1	100.0	59.2	100.0	32.5	57.6	0	0	0	0	42.3	79.0
Mahbubnagar													
Aurupalle													
Paddy	HYV	65.0	62.1	59.5	99.4	95.4	98.7	0	0	57.3	95.0	64.8	83.0
Dokur													
Paddy	HYV	53.2	59.9	50.7	100.0	105.0	100.0	115.0	78.4	82.7	81.2	64.6	89.0

was no indication that the latter would spontaneously follow because even after more than 20 years experience with fertilizers farmers had not shown any willingness to extend its use to nonirrigated crops. It follows that technological strategies (varieties and agronomic management practices) which generate high response under low rainfall (moisture) conditions, should receive highest priority in research for achieving real growth in productivity of nonirrigated crops (in low rainfall regions particularly).

In Akola (and Sholapur) there was no systematic pattern in the movement of rates or area fertilized over years or over farm size groups. It is important to study what factors bring about these variations.

Fertilizer use under rainfed conditions was significant only in Akola region and in Table 13 data on rates of application of different nutrients under irrigated and rainfed conditions have been presented for sorghum (HYV), paddy and cotton (HYV).

Table 13. Rate of application of fertilizers under irrigated and nonirrigated conditions for selected crops in Akola region.

Crops		Irrigated/ nonirrigated	Rate of application per fertilized ha (kg)		
			N	P_2O_5	K_2O
Sorghum	HYV	Irrigated	28	28	16
		Nonirrigated	29	15	9
Paddy	Local	Irrigated	59	33	18
		Nonirrigated	33	21	15
Cotton	HYV	Irrigated	41	29	27
		Nonirrigated	45	21	12

The table revealed an interesting feature. Except for paddy, the irrigated rates of application of nitrogen were not very different from the corresponding nonirrigated rates. With respect to phosphorus and potash, however, the irrigated rates were higher. It should be noted that this district has been identified as a relatively assured rainfall area having good scope for fertilizer use under rainfed conditions (Venkateswarlu 1979).

We would like to highlight one more aspect, and that is fertilizer use under pure and mixed cropping situations. Mixed cropping or intercropping is an important practice in semi-arid tropical agriculture (Jodha 1979) for several reasons. In Sholapur, Akola, Aurepalle and Dokur, the percentage of gross cropped area devoted to mixed cropping was 37, 78, 37, and 20%,

respectively. The mixed crops accounted for only 16 and 31%, respectively, of the total fertilizer used in Sholapur and Akola villages. In Aurepalle, the figure was negligible and in Dokur, no fertilizer was used on mixed crops. It thus appeared that fertilizer use was largely confined to pure or sole crop situation particularly in the low rainfall SAT regions. It has been shown (Jodha 1979) that mixed cropping is not followed on irrigated lands. If mixed cropping is viewed as a strategy to combat risks, this pattern is logical. Farmers who are concerned about protecting themselves against total crop failure (by resorting to mixed cropping) would not increase the risk of capital loss by using fertilizers.

The Akola situation has been analyzed more closely because of relatively higher extent of intercropping and higher use of fertilizers under mixed cropping situation in this region. Table 14 contains data on fertilizer use under pure and mixed cropping situations for sorghum, groundnut and cotton — the most important crops of the region around which different intercropping schemes are built.

The table clearly shows that for all the three crops, rates of fertilizer application were lower under intercropping situations. There is some evidence (Sahrawat et al. 1979) to show that at higher levels of fertilizer use, the response is lower under intercropping as compared to sole crop situation. Figures for percentage crop area fertilized indicated that intercropping systems built around groundnut and HYV of cotton were more extensively fertilized than those based on sorghum or local varieties of cotton. Indeed the extent of area fertilized under intercropping was higher than the corresponding sole crop situation for these crops. The data also revealed that intercrops based on high response varieties (sorghum and cotton HYV) were more extensively fertilized.

These findings highlight two issues which are important for intercropping research. Firstly, new intercropping systems for highly unstable, low rainfall areas must be based on the realization that from the farmers point of view these two strategies (fertilizer use and intercropping) are contradictory The latter reduces risk, the former increases it. Secondly, in other (better endowed) areas, alternative intercropping systems need to be based on relatively lower rates of fertilizer application.

5. Agronomic Management of Fertilizer Input

The evidence presented so far suggests that farmers are conscious of the relative responses of different crops to fertilizer application and take their decisions accordingly. We now present some data which indicate how farmers manage their fertilizer input — in terms of choice of fertilizer material, timing of application and use of different plant nutrients.

Table 14. Rate of application of plant nutrients per fertilized hectare (in kilograms) and extent of area fertilized for important crops grown under pure and mixed cropping conditions in Akola villages: 1975-78.

Crop		% crop area devoted to mixed cropping	Share of mixed crops in total NPK used on the crop	Rate of application per fertilized ha in kg for					
				Sole crop			Mixed crop		
				N	P_2O_5	K_2O	N	P_2O_5	K_2O
Sorghum	Local	97	65	20 (26)[a]	3 (66)	b (66)	11 (3)	6 (2)	4 (2)
	HYV	27	13	30 (64)	16 (35)	10 (35)	19 (25)	0	0
Groundnut		72	57	45 (11)	17 (34)	31 (11)	9 (29)	10 (28)	6 (20)
Cotton	Local	92	68	18 (70)	7 (55)	4 (45)	12 (18)	7 (13)	5 (13)
	HYV	39	41	47 (81)	23 (60)	13 (60)	36 (100)	22 (82)	15 (82)

a Figures in parentheses indicate percentage area fertilized

b Less than 0.5

These are important determinants of the technical efficiency of fertilizer use and this information would help identify aspects requiring more emphasis in extension programs.

(a) Sources of plant nutrients. Table 15 provides data on sources of different plant nutrients. It showed that in all the regions, bulk of the nitrogen was provided by straight fertilizers — mostly urea. Almost the entire quantity of phosphorus and potash was provided by fertilizer mixtures. A significantly higher fraction of nitrogen came from such mixtures in Akola region. Supplementary survey revealed that sale of fertilizer mixtures (prepared in the cooperative sector) was often tied to cooperative loans. Use of complex fertilizers was not noted anywhere except in Aurepalle. In all cases higher use of straight nitrogen forms provided flexibility in its use during the crop growth period. The Akola situation was somewhat different. Another important point revealed by the surveys was that farmers were more or less compelled to accept whatever fertilizer material was offered. The data presented in Table 15 did not fully reflect the preferences of farmers.

Table 15. Sources of different nutrients.

District/Village	Nutrients	Proportion of nutrients[a] provided by	
		Straight fertilizers	Fertilizer mixtures
Sholapur	N	79	21
	P_2O_5	12	88
	K_2O	8	92
Akola	N	65	35
	P_2O_5	7	93
	K_2O	0	100
Mahbubnagar			
Aurepalle	N	74	24
	P_2O_5	0	86
	K_2O	0	100
Dokur	N	85	15
	P_2O_5	0	100
	K_2O	0	100

a In some cases (N and P_2O_5 in Aurepalle), the two do not add up to 100. This is because of some complex fertilizers (DAP) being used.

(b) Balanced use of plant nutrients. Balanced use of plant nutrients is an important determinant of fertilizer use efficiency. We examined the $N:P_2O_5$ use ratios in different regions on the basis of aggregate consumption of these nutrients. These came to 4.0:1, 2.6:1, 3.2:1, and 3.6:1 in Sholapur, Akola, Aurepalle and Dokur, respectively. Thus, in all regions fertilizer use was heavily biased towards nitrogen. The situation in Sholapur and Dokur reflected relatively greater imbalance.

Table 16 looks at this problem from the point of view of area fertilized with different nutrients. It shows that only a little more than one-third of the total fertilized area received all the three major nutrients in the low rainfall regions of Sholapur and Mahbubnagar. Use of potash was not recommended for most crops in these regions. In Akola,

Table 16. Distribution of fertilized area according to use of different nutrients (1975-78).

District/ Village	Percentage of fertilized area receiving				
	Nitrogen only	Phosphorus only	$(N+P_2O_5)$	$(N+P_2O_5+K_2O)$	Total fertilized area
Sholapur	63	1	2	34	100
Akola	26	4	0	70	100
Mahbubnagar					
Aurepalle	58	0	6	36	100
Dokur	65	0	0	35	100

where its use was recommended for crops like HYV of sorghum, cotton and wheat, 70% of the fertilized area received potassic fertilizers. The imbalance in the use of phosphorus was unambiguous. In all regions except Akola, 60 to 65% of the fertilized area did not receive any phosphatic fertilizer. It may be noted again that the fertilizer credit policy adopted by the cooperatives played an important role in achieving a relatively more balanced use pattern in Akola.

It should be noted that these soils are generally not deficient in potash and with respect to phosphorus too, the response under dryland conditions has been low or non-significant (Venkateshwarlu 1979, Umrani 1979). This may be one reason for the observed imbalance. However, we have seen that in Mahbubnagar and Sholapur regions, most of the fertilizer was used for irrigated crops and this explanation would not hold. To some extent

the SAT reflects the trend obtaining in the country as a whole. It should be noted however, that the adverse long-term effects of this are likely to emerge more strongly on relatively poorer soils which predominate the Indian SAT. This aspect needs careful monitoring in view of the efforts being made to promote fertilizer use in such areas.

An imbalanced use pattern is usually the rule in the initial phases of fertilizer adoption because farmers start with nitrogenous fertilizers (Desai 1973). What causes concern is the persistence of this tendency even after 15-20 years experience with fertilizers, in areas which consume substantial quantities of fertilizers.[9]

(c) Timing of fertilizer application. Table 17 shows the average fertilization practice of farmers in terms of timing of nitrogen application. Use of phosphorus and potash was confined to basal application only.

Table 17. Timing of nitrogen application (1975-76).

District/ Village	Percentage of nitrogen users resorting to						
	Basal application (BA)	BA+one application	BA+two applications	BA+three applications	Post-basal application only		
					One application	Two applications	Three applications
Sholapur	33	7	0	0	49	10	0
Akola	65	9	a	a	21	4	0
Mahbubnagar							
Aurepalle	45	21	4	0	27	3	0
Dokur	20	26	12	6	20	12	4

a Negligible

It showed that in Sholapur, Akola and Aurepalle, single application of nitrogen (as basal or a single post-sowing application) was the dominant practice. In Dokur, majority of fertilizer users applied nitrogen more than once. Availability of irrigation offered great flexibility in this regard. These data also showed that post-sowing application of nitrogen was more important in Sholapur as compared to other regions suggesting that farmers were reluctant to commit investment in fertilizers at sowing time and preferred to follow a flexible pattern which afforded some protection against

9. In their study of the Guntur region — one of the most progressive districts in the country from the point of view of fertilizer use, Desai and others found a similar pattern (Desai et al. 1973).

uncertainty. This aspect has been recognized by agro-biological researchers also and the current thinking is that use of nitrogen for dry crops should be flexible and related to the available soil moisture (Venkateshwarlu 1979, Vijayalakshmi 1979, Umrani 1979).

(d) Further analysis of timing of fertilizer use. Figure 3 shows the monthly pattern of fertilizer ($N+P_2O_5+K_2O$) use in different regions during the three years. It revealed that generally the distribution had two peaks — one each corresponding to the two main cropping seasons. In the nonirrigated regions of Sholapur and Akola, the first peak was more pronounced. Because of the rainfall pattern (Umrani 1979) and the importance of rabi cropping in Sholapur, the first peak was hit somewhat late and thereafter fertilizer consumption declined slowly to rise again in November. In Akola, the first peak was attained in July after which fertilizer consumption declined sharply and the second peak occurred in November-December. In the Mahbubnagar villages fertilizer use followed the two paddy crops, the first season was spread longer due to split application of fertilizer on this crop.

Figure 3 also revealed considerable inter-year variation in the seasonal pattern of fertilizer use in all the regions. We hypothesized that these variations (seasonal as well as inter-year) were induced mainly by variations in the rainfall pattern. This hypothesis was tested with respect to variation in fortnightly consumption of nitrogenous fertilizers over the period June to November — the main season from the rainfall point of view. The simple model used involved regressing current and previous fortnights' rainfall on current fortnightly consumption of nitrogenous fertilizers.

$$F_t = f\,(RAIN_t,\ RAIN_t^2,\ RAIN_{t-1},\ RAIN_{t-1}^2)$$

Where F_t = Consumption of nitrogenous fertilizer during fortnight t expressed as percent of total nitrogen used during the year.

$RAIN_t$ = Rainfall in fortnight t in mms.

$RAIN_{t-1}$ = Rainfall in previous fortnight in mms.

$RAIN_t^2$, $RAIN_{t-1}^2$ = Square terms.

Data for all the three years were pooled and regressions for each region were estimated separately. These have been presented in Table 18.

The table shows that the estimated regressions explained a very small fraction of the total variation in the dependent variable, perhaps because of omission of several other variables like cropping pattern, sowing dates,

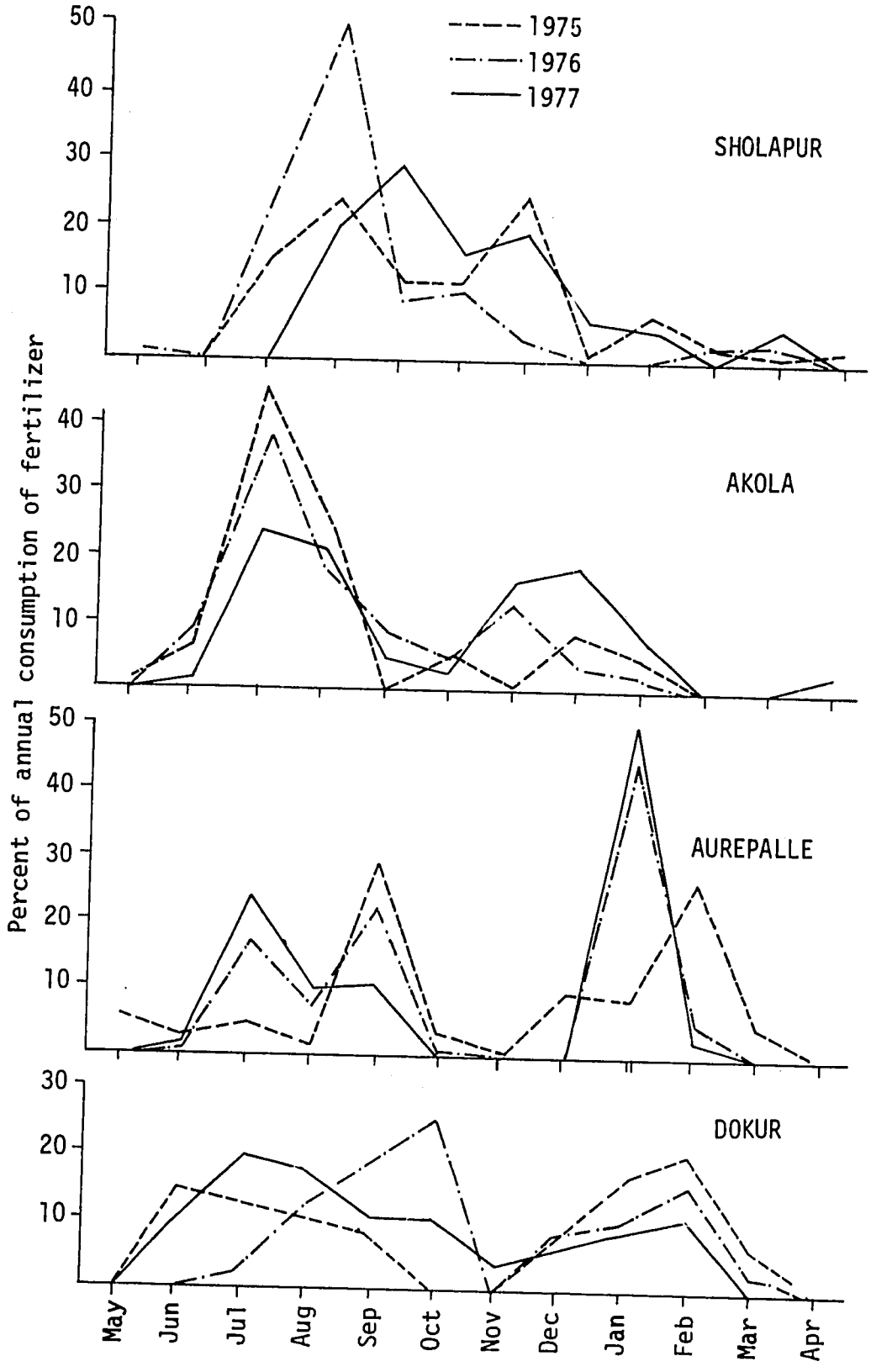


FIGURE 3. INTER-YEAR VARIATION IN SEASONAL PATTERN OF FERTILIZER ($N+P_2O_5+K_2O$) USE IN DIFFERENT REGIONS.

Table 18. Regressions showing the influence of rainfall on consumption of nitrogenous fertilizers in selected villages (1975-78).

Particulars/ Variables	Sholapur	Akola	Mahbubnagar	
			Aurepalle	Dokur
No. of observations	61	59	33	33
Intercept	4.930	6.962	3.055	3.221
$RAIN_t$	0.8E-3 (0.011)[a]	0.0232 (0.227)	0.0990*** (3.850)	-0.0144 (0.404)
$RAIN_t^2$	0.7E-5 (0.025)	-0.9E-4 (0.220)	-0.7E-3*** (3.904)	0.2E-4 (0.192)
$RAIN_{t-1}$	0.1179* (1.761)	-0.0150 (0.155)	-0.0067 (0.244)	0.0977** (2.619)
$RAIN_{t-1}^2$	-0.5E-3+ (1.569)	-0.1E-4 (0.038)	0.1E-3 (0.663)	-0.3E-3** (2.194)
R^2	0.055	0.021	0.081	0.208

a Figures in parentheses are t-values.
+, *, **, *** Statistically significant at 20, 10, 5, and 1% probability levels, respectively.

availability of irrigation, availability of fertilizers on time, etc. It was difficult to specify these variables and appropriate data were not available.

However, the regressions did indicate that variation in rainfall influenced the pattern of fertilizer use over different periods. This suggested that farmers' decisions regarding timing of fertilizer use were influenced by the behavior of rainfall — the major determinant of soil moisture in the rainy season. This effect was more clearly discernible in the low rainfall regions of Sholapur and Mahbubnagar. All the regression coefficients were statistically nonsignificant in Akola which had relatively higher and more stable pattern of rainfall. Except in Aurepalle, in all other equations rainfall during the previous fortnight turned out to be more important. In Aurepalle, where the land was relatively lighter textured and shallower (signifying lower moisture holding capacity), fertilizer use followed rains with a smaller lag. In both Mahbubnagar and Sholapur regions, the quadratic terms of the rainfall variable were negative. This implied that beyond a level, higher rainfall had an adverse effect on nitrogen use.

It may be recalled that in the Sholapur and Mahbubnagar regions, fertilizer use was largely confined to irrigated crops. Despite this the rainfall effect showed up more clearly in these regions as compared to Akola where fertilization of rainfed crops was common. Farmers in the low rainfall regions of the SAT thus appeared to be more responsive to changes in rainfall. Availability of irrigation did not diminish its importance.

6. Use of Organic Manures

Use of organic manures is the traditional fertilization practice of farmers. Farm yard manure, cakes, other organic wastes and sheep pennings were the materials used for this purpose in the selected villages. Of these, farm yard manure was the most important and we have looked at its use on the basis of data for 1975-76 and 1976-77. An idea regarding how use of organic manures and fertilizers is integrated is provided by Table 19 which shows the extent of area benefited from different manuring strategies.

Table 19. Use of organic manures and chemical fertilizers on farms (1975-77).

District/ Village	Percentage of cropped area receiving			
	Manuring from any source	Organic manure only	Chemical fertilizers only	Organic manure + fertilizers
Sholapur	13	7	5	1
Akola	42	17	20	5
Mahbubnagar				
Aurepalle	35	22	7	6
Dokur	46	5	29	12

The first column of the table showed that even in the most progressive Dokur village, more than half of the cropped area did not benefit from any kind of fertilization — organic or inorganic. Nearly 42 to 46% of the cropped area was covered under some kind of manuring in Akola and Dokur; only 13% of the area was so treated in Sholapur region. This suggested that exploitation of native soil fertility was higher in the relatively more unproductive region.

The table also revealed that the area receiving both fertilizers and manures constituted a relatively smaller proportion of the total area receiving fertilizers (column 3 + column 4) in Sholapur and Akola regions. It conveyed that manures and fertilizers were used as alternative fertilization strategies in these regions and the practice of integrated use of these two was not common. The proportion of fertilized area receiving organic manures also was nearly 29% in Dokur and 46% in Aurepalle. The Dokur case was special because in this village fertilized area exceeded manured area by a substantial margin and only about 30% of the manured area went unfertilized. There was thus some indication that in the Mahbubnagar region farmers were consciously attempting to integrate use of organic manures and fertilizers.

Table 20 provides data on percent crop area manured, average rate of manure application and the number of livestock per hectare of operated area in different areas. It revealed the poor status of manuring in the regions concerned. The percentage area manured varied from 7.5% in Sholapur to 27.8% in Aurepalle. The average intensity of manure application ranged from 0.2 tonnes (metric) to over 2 tonnes per hectare of gross cropped area. The actual rates were around 2-3 tonnes per manured hectare in the Sholapur-Akola regions and 8-9 tonnes in Mahbubnagar. The last column of the table showed that the availability of organic manures (proxied by cattle population per ha of operated area) was relatively better in the Mahbubnagar area.

Table 20. Average level of organic manure use on farms in different regions (1975-77).

District/ Village	Rate of organic manure application		Percent crop area manured	No. of livestock[a] per ha of operated area
	Per ha of gross cropped area (q/ha)	Per manured ha (q/ha)		
Sholapur	2.3	31.4	7.5	0.4
Akola	3.6	16.5	21.9	0.7
Mahbubnagar				
Aurepalle	23.3	84.0	27.8	0.9
Dokur	14.4	86.6	16.6	1.3

a Cows, bullocks, buffaloes including young stock.

Table 21 gives data on use of organic manures on irrigated and nonirrigated land. It clearly showed that in all the regions except Dokur, most of the organic manure was used for nonirrigated land. It may be recalled (Table 6) that fertilizer use was generally concentrated on irrigated lands in Sholapur, Aurepalle and Dokur. We have also shown (Table 19) that in Sholapur and Akola farmers used fertilizers and manures as

Table 21. Irrigation and use of organic manures (1975-77).

District/ Village	Share of irrigated land in total manure used(%)	Rate of application/manured ha (q)	
		Irrigated	Nonirrigated
Sholapur	34	38	28
Akola	2	40	16
Mahbubnagar			
Aurepalle	39	109	68
Dokur	98	88	20

alternatives (substitutes). The above table explains that this segmentation arose largely from alternative strategies adopted on irrigated and nonirrigated lands.

The Dokur case was important in that it showed that the nonirrigated lands were ignored with regard to any fertilization. Conjunctive use of fertilizers and manures on irrigated lands reflected a more balanced management of such lands, but in the process more than 40% of the cropped land went without any kind of fertilization. Table 21 also revealed that the rates of manure application were significantly higher on irrigated lands in all the regions. These ranged from about 4 tonnes per hectare in Sholapur-Akola regions to 9-11 tonnes in Mahbubnagar. The nonirrigated rates lay in the neighborhood of 2-3 tonnes except in Aurepalle where it was nearly 7 tonnes.

The data presented in this section indicated that a sizeable fraction of cultivated land was left unmanured. It is difficult to accept that farmers would do so year after year and deliberately starve their cultivated land. To investigate this, the manuring history of all plots which were manured during any of the three years (1975-76 through 1977-78) was examined. The results have been summarized in Table 22.

Table 22. Frequency of use of organic manures.

District/ Village	Proportion of plot manured		
	Once in three years or more	Twice in three years	All three years
Sholapur	78	15	7
Akola	69	27	4
Mahbubnagar			
Aurepalle	62	26	12
Dokur	52	26	22

The table shows that generally, plots were not manured every year. In most cases manuring was done once in three years or more. This implied that in any given year, a maximum of one-third of the crop area would be manured. Data presented in Table 19 showed lower values indicating even greater time lag between manurings. One would need data for more than three years to arrive at the exact picture. However, Table 22 did reflect the strategy adopted by farmers facing inadequate supplies of manures.

There was some evidence to show that villages with higher irrigation (and on small farms where the livestock-arable land ratios were higher), some area was fertilized more frequently. In Mahbubnagar villages where two crops were often grown on irrigated plots, 38 to 48% of the plots were manured every year or every alternate year.

Information on use of organic manures was also collected in the special surveys. The responses indicated that all farmers used organic manure and almost each one felt that the existing supplies were inadequate to cover the entire cropped land at desirable rates. The desirable rates for nonirrigated lands were expressed as 4-6 tonnes per hectare in the Sholapur-Akola region and 6-8 tonnes in Mahbubnagar area. For irrigated lands, the corresponding values were 6-8 tonnes and 9 to 12 tonnes per hectare, respectively. Reference to Table 21 revealed that except on irrigated land in Mahbubnagar (and nonirrigated land in Aurepalle) the actual rates of application were much lower. The survey also revealed that manuring every year (and in some cases, every season) was confined to irrigated plots in Mahbubnagar (and also Akola) region. The normal practice was to apply organic manure once in 3-4 years depending upon availability of supplies. The survey also revealed that the early summer months were preferred by farmers for spreading manures because bullock carts had access to all fields and sufficient time was available for proper decomposition.

These findings indicated that farmers were aware of the value of manuring but because of inadequate availability, had to reduce the rates of application as well as area fertilized. In spite of this, a conscious attempt was made to manure the more intensively cultivated lands at higher rates.

IV. DETERMINANTS OF FERTILIZER USE

Wide variability in fertilizer use between plots, farms, regions and years was revealed by the VLS data. From the results presented in the preceding section, it was possible to identify some major influences like irrigation, the profitability of fertilizer application, and rainfall. A more rigorous analysis on determinants of fertilizer use is attempted in this section.

Empirical studies seeking to explain inter-farm variability in fertilizer use have usually considered variations in average rate of fertilizer application per farm (NCAER 1974, Colmanares 1975). In a situation where all the area is not fertilized this is a poor indicator of the variability in the level of fertilizer use. Accordingly, we considered three indicators of fertilizer use — average rate of fertilizer application, actual rate of application per fertilized hectare and extent of crop area fertilized, as dependent variables in our models. This also enabled us to test whether rate and extent of area fertilized variables were influenced by the same set of casual factors. This is an important methodological issue and may have policy implications.

We postulated that inter-farm variations in fertilizer use arose from differences in (a) the socio-psychological attributes of the farmers, (b) their resource endowments and (c) their perception regarding profitability of fertilizer use. In context of spatial (interregional) and temporal variability, two more forces become important; (d) the institutional setting and (e) agroclimatic differences.

The empirical model, however, would look different depending upon the data being analyzed. For example, the institutional and agroclimatic variables would not figure if the data pertained to a single village and year. It is also clear that the profitability of fertilizer use variable is difficult to specify. It becomes necessary to use proxies by including variables which are measurable (on which data are available) and which affect the response of crops to and profitability of fertilizer application.[10]

In the village level studies, a plot is the ultimate unit of observation and so data (on inputs and output) were available for each plot owned by the farmer. This provided the opportunity to analyze inter-plot differences which may arise from differences in soil texture, ownership status of the plot, the nature of crop grown on the plot, etc. Accordingly, we used two approaches — one based on farm level data and the other based on plot level data used in the regressions. Table 23 provides the specification and hypothesis pertaining to each variable used in the two analyses.

The farm level regressions were based on the following model:

AVNPK or NRATE or NAREA = f (AGE, EDUCATON, EXPERNCE, RISKAVER, FARMSIZE, IRRIGATE, LUCK, HHSIZE, COMCROPS, CREDIT, FRTPRICE, RAIN, RAINSQ, VDUMMY1, VDUMMY2, VDUMMY3, VDUMMY4, VDUMMY5, YRDUMMY1, YRDUMMY2).

---

10. See Jha 1980 for review.

Table 23. Definition of variables used in regression models explaining inter-farm and inter-plot differences in fertilizer use.

Abbreviation	Expected relation-ship	Analysis	Variable specification
Dependent Variables			
1. AVNPK	-	Farm/plot	Total plant nutrients ($N+P_2O_5+K_2O$) used per hectare of cropped area on the farm (or plot) in kg.
2. NRATE	-	Farm/plot	Rate of application of nitrogen per fertilized hectare on the farm (or plot) in kg.
3. NAREA	-	Farm	Percentage cropped area fertilized with nitrogenous fertilizers (%).
Explanatory Variables			
I. Socio-psychological factors			
1. AGE	b < o	Farm/plot	Age of the head of the farm household in years.
2. EDUCATON	b > o	Farm/plot	Education of the head of the household expressed as score based on years of formal education.
3. EXPERNCE	b > o	Farm/plot	Number of years since initial use of fertilizers.
4. RISKAVER	b < o	Farm/plot	Score measuring extent of risk aversion of the farmer (Binswanger 1979).[a]
II. Resource endowment and plot-related factors			
5. FARMSIZE	b < o	Farm/plot	Operated area of the farm in hectares.
6. IRRIGATE	b > o	Farm/plot	Percent irrigable area on the farm. Dummy variable with value 1 for irrigated plots.
7. HHSIZE	b > o	Farm/plot	Number of family members.

Table 23. Contd.

Abbreviation	Expected relation-ship	Analysis	Variable specification
8. SOILDMY1	b > o	Plot	Dummy having value 1 for plots having deep black soils.[b]
9. SOILDMY2	b > o	Plot	Dummy having value 1 for plots having medium-deep black soils.
10. PURECROP	b > o	Plot	Dummy having value 1 if pure crop sown on the plot and 0 if crop mixtures were sown.
11. OWNPLOT	b < o	Plot	Dummy having value 1 for leased-in and 0 for owned plots.
12. HYVDMY	b > o	Plot	Dummy having value 1 for plots sown with high yielding varieties and 0 if sown with traditional varieties.
III. Institutional factors			
13. COMCROPS	b > o	Farm/plot	Percentage area under commercial crops on the farm.[c]
14. CREDIT	b > o	Farm/plot	Total borrowings of the farmer during the year in rupees.[d]
15. FRTPRICE	b < o	Farm/plot	Price paid per kg of plant nutrient by the farmer in rupees.[e]
16. PROPRICE	b > o	Plot	Lagged average village price of the crop grown on the plot in rupees per quintal.
IV. Agroclimatic factors			
17. RAIN	b > o	Farm/plot	Rainfall during June to November (or June to August in the village in mms.
18. RAINSQ	b < o	Farm/plot	Square of the above rainfall variable.
19. VDUMMY1		Farm/plot	Dummy variable for Aurepalle village (Mahbubnagar).

Table 23. Contd.

Abbreviation	Expected relation-ship	Analysis	Variable specification
20. VDUMMY2		Farm/plot	Dummy variable for Dokur village (Mahbubnagar).
21. VDUMMY3		Farm/plot	Dummy variable for Kinkheda village (Akola).
22. VDUMMY4		Farm/plot	Dummy variable for Kanzara village (Akola).
23. VDUMMY5		Farm/plot	Dummy variable for Kalman village (Sholapur).
24. YRDUMMY1		Farm/plot	Dummy variable for 1975-76 year.
25. YRDUMMY2		Farm/plot	Dummy variable for 1976-77 year.

a The risk aversion score for each farmer was derived from the results of an experiment involving a series of gambling games. The risk aversion coefficients so derived were influenced by the outcome of the preceding game. In order to control this, a variable LUCK was introduced as an explanatory factor. This variable has no other significance.

b The soil types considered in the VLS were: deep black, medium black, medium to shallow black, deep red, shallow red, gravelly, saline or other problem soils, and others.

c The crops considered were sugarcane, vegetables, cotton, groundnut and castor.

d The way it is defined this variable also includes consumption loans. It was not possible to sort out all the loan transactions. In order to minimize the chances of consumption loans entering into this variable, all credit transactions below Rs. 50 were excluded. Still, this variable is weakly specified.

e If only straight fertilizers were used, the calculation of price per kg of nutrient was easy. However, if mixtures or complex fertilizers, containing more than one nutrient were used, the calculations became involved. In such cases, prices of individual nutrients were obtained by apportioning the total expenditure on fertilizers in terms of quantities of individual nutrients weighted by the prices of these nutrients in straight fertilizers. Average price per kg of total plant nutrients ($N+P_2O_5+K_2O$) was also obtained by a similar weighting procedure. The appropriate price variable (total plant nutrient or nitrogen) was used for each dependent variable.

The plot-level analysis contained the following variables:

AVNPK or NRATE = f (ACE, EDUCATON, EXPERNCE, RISKAVER, FARMSIZE, HHSIZE, LUCK, SOILDMY1, SOILDMY2, IRRGDMY, PURECROP, OWNPLOT, HYVDMY, COMCROPS, CREDIT, FRTPRICE, PRDPRICE, RAIN, RAINSQ, VDUMMY1, VDUMMY2, VDUMMY3, VDUMMY4, VDUMMY5, YRDUMMY1, YRDUMMY2).

In the farm-level analysis, only those farmers were included who had used fertilizers. Similarly, in the plot-level analysis, data for only fertilized plots were considered. Linear regression equations containing all the variable mentioned above were estimated using pooled data. Subsequently, equations were also estimated for each of the three regions — Sholapur, Akola and Mahbubnagar, separately.[11]

Appendices II and III contain the estimated equations from farm level and plot-level data. The results have been summarized in Tables 24 and 25 for the respective analyses and show the observed effects of variables which were significant at 80% or higher probability levels. We have integrated the results of the two analyses in the discussion that follows. The following paragraphs describe the results under each of the four broad factor groups mentioned earlier.

1. Personal Characteristics

Personal traits of the farmer assume particular significance in context of use of modern inputs in farming. The plot level regressions (Table 25) gave better results with regard to this set of variables. The results indicated that farmers with higher education and longer experience used higher levels of fertilizers. This effect was discernible in Akola and Mahbubnagar regions. These variables were not significant in any of the Sholapur equations.

Risk aversion was another personal characteristic considered. In Sholapur region, the hypothesized effect was noted and fertilizer rates were negatively related to the degree of risk aversion (Table 25) Mahbubnagar plot level equations, however, showed inconsistent signs. In the farm level regressions (Table 24), the effect of this variable showed up on the fertilized area variable in two out of four equations and also on rate

---

11. Aurepalle and Dokur (Mahbubnagar) villages were not distinguished because these differed mainly in irrigation intensity and this variable was explicitly included in the models.

Table 24. Variables influencing inter-farm variation in fertilizer use.[a]

Variables	AVNPK				NRATE				NAREA			
	Pooled	Sholapur	Akola	Mahbubnagar	Pooled	Sholapur	Akola	Mahbubnagar	Pooled	Sholapur	Akola	Mahbubnagar
I Personal factors												
AGE												
EDUCATON												
EXPERNCE	(+)				(+)				(+)			
RISKAVER						(-)			(-)			(-)
II Resource endowments												
FARMSIZE	(-)		(-)	(-)					(-)		(-)	(-)
IRRIGATE	(+)	(+)	(+)	(+)			(+)		(+)			(+)
HHSIZE				(+)	(+)				(-)		(-)	
III Institutional factors												
COMCROPS	(-)			(-)	(-)						(+)	(-)
CREDIT	(+)								(+)			(+)
FRTPRICE	(+)		(+)		(-)			(-)				
IV Agroclimatic factors												
RAIN	(+)	(+)			(+)			(+)	(+)			
RAINSQ	(-)	(-)			(-)			(-)	(-)			
VDUMMY1 (AUR)	(+)	b	b	b	(+)	b	b	b	(+)	b	b	b
VDUMMY2 (DOK)	(+)	b	b	b	(+)	b	b	b		b	b	b
VDUMMY3 (KIN)	(+)	b	b	b		b	b	b	(+)	b	b	b
VDUMMY4 (KAZ)	(+)	b	b	b		b	b	b	(+)	b	b	b
VDUMMY5 (KAL)		b	b	b		b	b	b		b	b	b
YRDUMMY1 (75-76)	(-)		(+)	(-)			(+)	(+)	(-)		(+)	(-)
YRDUMMY2 (76-77)	(-)		(+)				(+)			(-)	(+)	

a See Appendix II for regressions.
b Variable not included in the equation.

Table 25. Variables explaining inter-plot variability in fertilizer use.[a]

Variables	AVNPK				NRATE			
	Pooled	Sholapur	Akola	Mahbubnagar	Pooled	Sholapur	Akola	Mahbubnagar
I Personal factors								
AGE					(+)			
EDUCATON	(+)			(+)	(+)			(+)
EXPERNCE	(+)		(+)	(+)	(+)		(+)	
RISKAVER		(-)		(+)		(-)		(+)
II Plot & farm resources								
FARMSIZE	(-)				(-)	(+)		
HHSIZE	(+)		(+)	(+)	(+)		(+)	
IRRIGATE	(+)	(+)	(+)		(+)	(+)	(+)	
SOILDMY1			(+)				(+)	
SOILDMY2	(+)		(+)	(+)		(-)	(+)	
PURECROP	(+)		(+)		(+)		(+)	
OWNPLOT								
HYVDMY								
III Institutional factors								
COMCROPS	(-)			(-)	(-)		(-)	(-)
CREDIT								
FRTPRICE					(-)		(-)	(-)
PRDPRICE								
IV Agroclimatic factors								
RAIN	(+)							
RAINSQ	(-)			(-)	(-)			(-)
VDUMMY1 (AUR)	(+)	b	b	b		b	b	b
VDUMMY2 (DOK)		b	b	b	(+)	b	b	b
VDUMMY3 (KIN)	(+)	b	b	b	(+)	b	b	b
VDUMMY4 (KAZ)	(+)	b	b	b	(+)	b	b	b
VDUMMY5 (KAL)	(+)	b	b	b		b	b	b
YRDUMMY1 (75-76)					(+)			(+)
YRDUMMY2 (76-77)	(-)							

a See Appendix III for regressions.
b Variable not included in the equati

of application of nitrogen in Sholapur region. It thus appears that in relatively unstable areas (like Sholapur), risk aversion did act as a deterrent to fertilizer use. In other areas this effect did not seem to be important.

2. Resource Endowments

The farm level regressions (Table 24) showed quite clearly that the average levels of fertilizer application and the extent of crop area fertilized were lower on larger farms. This effect was pronounced in Akola and Mahbubnagar regions. Table 25 showed a similar influence on rate of fertilizer application on pooled data but in the regional equations for Akola and Mahbubnagar this variable was not found significant. In the Sholapur region, there was some indication of a positive relationship between farm size and rate of fertilizer application. Thus, in general, larger farms were characterized by lower fertilizer use intensity, but in some areas (where the extent of fertilizer use was low) a reverse trend could also prevail. It has been argued that in the initial phases of fertilizer adoption, farm size could be positively associated with fertilizer use. Clear results were not obtained with respect to the household size variable. The farm level regressions revealed a mild positive influence of this variable on rates of fertilizer application, but on extent of area fertilized the coefficients were negative in two out of four equations. Plot level regressions however showed its positive effect on rate of fertilizer application. It should be noted that larger family size implied higher subsistence pressure, better availability of family labor and better access and exchange of information. All this should affect fertilizer use positively. There was some indication to this effect but the results for fertilized area turned out to be inconsistent.

Irrigation, as expected, was found to exercise a positive effect on fertilizer use. The effect showed up more strongly on fertilization rate in the plot level regressions because this variable was specified in a more relevant manner in this analysis.[12] The coefficients of this variable in the Mahbubnagar equation (Table 25) were not significant probably because of lack of variability — almost all fertilized plots were irrigated in this region. It thus appears that irrigation influenced decisions regarding actual rate of application to be used more strongly, though its effect on fertilized area was also significant.

There was an indication (Table 25) that black soils were fertilized at higher levels than other soil types and that deeper soils were fertilized at higher levels than the shallower soils. This trend was noted in Akola and

---

12. In the farm level analysis, average irrigation intensity was considered whereas in the plot level analysis the status of this variable in the plot actually fertilized was specified.

Mahbubnagar regions — the Sholapur nitrogen rate equation had an inconsistent sign, perhaps because of the predominance of deep black soils in this region.

It was hypothesized that mixed crops were fertilized at lower levels as compared to pure crops (Table 14). Regression results also supported this hypothesis and this variable was found to be significant in the pooled as well as Akola equation (Table 25). It may be recalled that it was in Akola region only that the mixed crops claimed a significant share of the total fertilizers used.

The regressions did not show any influence of plot ownership and high-yielding varieties on fertilizer use decisions. While the former can be explained by very limited number of leased-in fertilized plots, the latter was surprising and went against the well accepted view. Scrutiny of data revealed that this dummy variable was highly correlated with irrigation and pure crop variables. These appeared to capture the influence of the variety variable also.

3. Institutional Factors

Credit was hypothesized to be a major factor affecting fertilizer use. This variable emerged significant in only a few farm level regressions; the plot level regressions did not show this variable to be significant in any case. The results thus did not reveal this variable to be overwhelmingly important. It should however be noted that this variable was specified as the total borrowings of the farmer — irrespective of its use. This specification might have led to indifferent results for this variable. The extent of commercialization was also hypothesized to influence fertilizer use positively. In almost all the pooled equations it had the wrong sign. These results also stemmed from poor specification. It may be recalled that area under commercial crops like cotton, groundnut, castor, sugarcane and vegetables was used to depict this variable. The last two had insignificant acreage and the rest were primarily rainfed crops having lower fertilizer use values. This variable thus appears to capture irrigation (or lack of it) more strongly than commercialization.

Fertilizer price had the expected sign in most of the equations where it was significant. Exceptions were the farm level regressions (Table 24) which showed this variable to be perversely related to average rate of fertilizer application but in this case also the signs were correct for the nitrogen rate equation. The results indicated that changes in fertilizer prices affected rate of application decisions: in extent of area fertilized equation, this variable was not found to be significant. It should be noted that a significant source of inter-farm variability in prices was the composition of the fertilizer basket of the farmer. Response to this factor thus implied awareness of the real price of fertilizer nutrients.

The produce price variable did not emerge significant in any equation, probably because this variable had only inter-village and temporal variability. We could not use farm-specific values for output prices.

4. Agroclimatic Factors

The most important result under this category of variables pertained to rainfall. The farm level regressions revealed that rainfall was an important determinant of decisions regarding rate as well as extent of area fertilized. The regional equations came out poorer because the range of variability was reduced substantially. The equations also indicated that very high rainfall affected nitrogen use adversely. The significance of village and year dummies in several equations emphasized location and time induced variability in fertilizer use.

This analysis provided some useful insight into the decision making process of the farmers. It was noted, however, that in most cases, a large proportion of the variability in the fertilizer use parameters remained unexplained (Appendix II and III). This indicated the need and scope for modification and improvement in the models. The regression results also indicated that by and large, both rate and area fertilized decisions were influenced by the same set of broad factors. However, there was enough distinction to justify separate analysis of these two parameters.

We now look at interregional variability in the results. Fertilizer use was lowest in Sholapur region (various tables in Section III). The regressions indicated that fertilizer use in this region was primarly determined by soil moisture conditions. Irrigation and rainfall during the growing month were the primary determinants. There was also an indication that risk aversion and experience variables influenced decisions regarding rate of fertilizer application. These results are consistent with the high risk environment characterizing this area.

In Akola, fertilizer use was higher and nonirrigated crops were also fertilized. Irrigation, household size, experience, fertilizer price, and agronomic factors like soil type and cropping were found to be important in this region. Fertilizer use was inversely related to farm size. Interestingly, rainfall did not appear as a significant variable in any equation for this region. It may be recalled that this region received relatively higher and more stable rainfall as compared to other regions studied.

In Mahbubnagar, fertilizer use was confined to irrigated crops only. Farmers with higher level of irrigation used more fertilizers. Education and experience were the important personal factors affecting fertilizer use in this region. There were indications that fertilizer price, household size, and rainfall were also important. The farm and plot level regressions gave contradictory results for the risk aversion variable.

The salient results of the regression analysis can be summarized as follows:

(a) Soil moisture was the most important determinant of fertilizer use in the semi-arid tropics. Areas and farms having well developed irrigation resources were much better in this regard and had higher fertilizer use. In low rainfall (nonirrigated) areas, fertilizer use was influenced by fluctuations in rainfall. Fertilizer recommendation for rainfed areas and crops must therefore be flexible and tailored to specific seasonal conditions.

(b) The knowledge of the farmer emerged as an important determinant. This emphasized the role of proper extension in popularizing fertilizer use in the semi-arid tropics. Risk aversion was found to be important only in the highly unstable regions of Sholapur. In Akola, where bulk of the fertilizers was used under rainfed conditions, its effect was not noticeable. It is quite clear that risk aversion was not a universal deterrent to fertilizer use. In areas where the environment itself was highly risky this factor assumed significance.

(c) Fertilizer price and credit emerged as important institutional factors. The results indicated that farmers were responsive to changes in real prices of fertilizer nutrients. With respect to credit, the results of this analysis were not very sharp.

(d) The results with respect to plot specific characters suggested that farmers took their fertilizer rate decisions on the basis of expected response. The rates were higher on plots having better water-retentive capacity and on plots put to pure crops rather than intercrops.

(e) Regional and temporal effects were quite important in terms of fertilizer use. These could relate to seasonal conditions, occurrence of pests and diseases, availability of fertilizer, market and fertilizer distribution network, etc. Micro-level analysis cannot fully capture these influences.

(f) The results also indicated that from the point of view of encouraging fertilizer use, it would be appropriate to classify the semi-arid tropics in terms of stability or risk in the environment. High instability would call for a different set of strategies as compared to areas having stable and/or relatively higher rainfall.

Determinants of Organic Manure Use

A similar regression model was specified to analyze decisions regarding use of organic manures also. Appendixes IV and V contain the results of the farm and plot-level regressions. The main conclusions are summarized below.

(a) Older and more risk averse farmers used higher levels of organic manures. Positive influence of education and experience with fertilizers was also indicated by the results.

(b) In general, larger farms and farms with smaller households used less organic manures. Irrigation exercised a negative influence in Akola but in Mahbubnagar, a positive effect of irrigation on organic manure use was noted. Both the rate and area manured variable were influenced by the status of livestock assets on the farm.

(c) There was an indication that plots sown with high yielding varieties were manured at higher rates. Relatively lower rate of manuring was used on leased-in as compared to owned plots.

Use of organic manures on farms was thus significantly influenced by the personal attitudes of the farmer and the level of livestock resources. It was also indicated that farmers devoted greater attention to their own plots and areas sown to high yielding varieties.

V. SUMMARY AND CONCLUSIONS

The main focus of this paper was on understanding the fertilization practices of farmers in different agroclimatic regions of SAT India. Data from ICRISAT Village Level Studies, being conducted in three agroclimatic areas (Sholapur, Akola and Mahbubnagar) were used for this purpose.

Results on adoption pattern of fertilizers revealed that fertilizer use started in Mahbubnagar region well before the sixties but the pace of its diffusion differed between areas having different intensities of irrigation development. In Dokur where nearly 60% of the area was irrigated, almost all farmers used fertilizers. The proportion was markedly lower in Aurepalle with about 20% irrigated area. Sholapur region represented another extreme with very low adoption levels. Fertilizer use in this area started in mid-sixties but the pace of diffusion has been very slow. On the other hand, Akola region was characterized by very rapid pace of diffusion since 1965 or so. It was also found that while most of the fertilizer users in Mahbubnagar and Akola regions belonged to the continuous user category, in Sholapur, a large proportion of farmers used fertilizers intermittently. Thus, adoption was found to be higher and consistent in highly irrigated areas and in areas where commercial crops were important. There was evidence to suggest that it was positively correlated with farm size.

Lack of irrigation and working capital were expressed as the main reasons for nonadoption of fertilizers. Risk was also expressed as an important consideration by several farmers in Akola region. In other areas too, indirect evidence on the role of risk was provided by the fact that very little fertilizer was used for dry crops.

The average level of fertilizer ($N+P_2O_5+K_2O$) use was found to be only 2 kg per hectare of cropped area in Sholapur region. The levels in Akola, Aurepalle and Dokur were 7 kg, 12 kg, and 39 kg per hectare respectively. These low levels arose mainly because a very small proportion of the cropped area was fertilized. The actual rates of application (kg N/fertilized ha) varied from 14 to 18 kg in different regions under nonirrigated conditions and from 60 to 65 kg under irrigated conditions in Mahbubnagar and Akola villages. In Sholapur, the irrigated rate was 39 kg per hectare. In Mahbubnagar, nearly the entire fertilized area was irrigated but in Akola, more than 80% of the fertilized area was nonirrigated.

Irrigated crops (paddy) accounted for nearly all the fertilizer used in Mahbubnagar; in Sholapur also, these claimed over 75% of the total fertilizers used. In Akola, bulk of the fertilizer was used for rainfed crops (cotton, high yielding varieties of sorghum groundnut) but in this region also the irrigated crops received preference. Wheat and paddy were grown on only about 4% of the cropped area but these accounted for nearly one-third of the total fertilizer used. The pattern of fertilizer allocation for irrigated as well as rainfed crops supported the hypothesis that only high response crops were fertilized. Fertilization of post-rainy season sorghum in Sholapur suggested that stability of response was also an important factor.

The results indicated that in spite of more than 10 years experience with fertilizers, its use continued to be concentrated on the same set of crops with which farmers started. The crop base was narrow, largely because the nonirrigated crops were not fertilized or were fertilized less extensively. The case of the low rainfall regions was particularly vulnerable in this regard. Farmers were generally aware that under normal conditions even the traditional varieties showed some response to fertilizers. Uncertainty about the season and inadequacy of capital were the most important constraints inhibiting fertilizer use under rainfed conditions.

An important feature revealed by this analysis was that a significant fraction of the irrigated land was not fertilized (Jha 1980). Even in Dokur, about 20 to 30% of the irrigated land went without any fertilizers — in other regions the figures were much higher. This has important implications for future growth in fertilizer use and productivity in the SAT. Exploitation of this slack is being attempted in a big way under the Intensive Fertilizer Promotion Campaign.

In general, rates of fertilizer application and extent of crop areas fertilized were higher in Mahbubnagar region and Sholapur fared worst in this regard. In all regions, the rates were significantly lower than the recommended levels. Crops like paddy, sugarcane, wheat and cotton were fertilized at higher levels as compared to others. Rates and extent of area fertilized were higher for irrigated crops and for more fertilizer responsive varieties. An important feature noted was that mixed crops were not

fertilized under low rainfall situations. In relatively higher rainfall areas these were generally fertilized at lower rates as compared to sole crops. However, the extent of area fertilized was higher for mixed crops based on high yielding varieties.

Study of the fertilizer management practices of farmers revealed that use of phosphorus and potash was very low and the N:P ratio was heavily biased towards nitrogen. Akola was the exception where nearly three-fourth of the fertilized area received some phosphorus also. This was largely because of the fertilizer credit policy adopted by the cooperatives. Fertilizer credit was given in kind and farmers were compelled to buy fertilizer mixtures produced in the cooperative sector. It was also observed that post-sowing application of fertilizer was quite common in Sholapur region. This was probably a risk adjustment mechanism which provided greater flexibility in use of this costly input. It was also noted that in most cases single applications of fertilizer were done, either as basal or post-basal applications. Further analysis of the seasonal pattern of fertilizer use revealed that in Sholapur and Mahbubnagar regions, rainfall influenced fertilizer use.

Analysis of the pattern of organic manure use indicated that manures and fertilizers were used as substitutes in Sholapur and Akola regions but in Mahbubnagar, this use was complementary. Except in Dokur, all other regions bulk of the organic manures were used on nonirrigated lands. In general, the rates of application were substantially higher on irrigated plots.

Shortage of organic manures was universally felt. Two kinds of adjustments were made by farmers. In a small measure (as in Sholapur and Akola) they used fertilizers as a substitute. The more important mechanism was rotation of plots manured. Each plot was manured at 3-4 years interval. Eventhough this was the general practice, an attempt was made to increase the frequency of manuring for plots which were cultivated more intensively.

The contrast between Sholapur or even Aurepalle and Dokur situations can be used to extrapolate the likely impact of irrigation development in low rainfall SAT environment. This intensification has implications for cropping pattern which are well-known (Jodha 1977) viz. switch from low-value, low-response crops to high value crops. In terms of fertilizer use, our analysis suggests that this also leads to concentration of fertilizer (and manure) use on irrigated crops. This is inevitable so long as capital constraints necessitate such choices. It implies that the highly productive inputs will be concentrated on the irrigated lands and nonirrigated crops would suffer further. The only force which can break this process is rapid advance in the production technology of dry crops.

Results of the regression-based analysis on determinants of fertilizer use indicated that the status of soil moisture (determined by irrigation and rainfall) was an important factor influencing fertilizer use. The level of knowledge of the farmer, measured by experience and education also

exercised an influence. Risk aversion was not found to be an important constraint everywhere — it was only in highly unstable production regions (Sholapur) that this factor emerged significant. Credit and fertilizer prices were found to influence fertilizer use decisions.

Results with respect to plot specific characters suggested that farmers took their fertilizer rate decisions on the basis of expected response. The rates were higher on plots having better water retentive capacity and on plots put to pure rather than mixed crops.

The use of organic manures on farms was significantly influenced by the personal attributes of the farmer — his age, education, expereince and risk aversion. The most important determinant of organic manure use was its availability, measured by the status of livestock population on the farm. Farmers were also found to devote greater attention to their own (rather than leased in) plots and to areas sown with high yielding varieties.

The results suggest several useful clues to alleviate the constraints — some relating to agro-biological research and some to developmental and institutional strategies. These are enumerated below:

Agricultural Research

1. Fertilizer responsiveness is the most crucial variable affecting fertilizer use decisions. This implies continued emphasis on this character in crop improvement work.

2. There is need to focus attention on low rainfall regions and fertilizer responsiveness under constrained soil moisture conditions.

3. There is need to evaluate fertilizer management practices which are based not on *a priori* assumptions about soil moisture conditions but on *ex post* evaluation of actual conditions.

4. The response of intercropping systems to fertilizer application needs to be carefully analyzed. The problem is particularly crucial for low rainfall areas.

Development and Institutional Strategies

1. The importance of irrigation need not be over-emphasized. What must be noted is the possible impact of irrigation on the production on nonirrigated lands.

2. Credit was expressed to be a crucial constraint and all-out efforts are required to evolve a viable credit strategy to suit the requirements of an unstable agricultural system. This must replace the present ad hoc policies with regard to subsidies, suspension of loans, etc.

3. The fertilizer distribution system can play an important role in ensuring balanced use of fertilizers. On the other hand, it could also accentuate the imbalance if, for example, the correct fertilizer formulations are not available at the right time.

4. Lack of awareness regarding recommended levels of fertilizer application, even in a progressive village like Dokur, reflects poorly on the quality of the agricultural extension system.

5. There is also a need to shift from single-valued recommendations regarding fertilizer use to a dynamic program which is based on seasonal conditions as they unfold. This calls for constant monitoring of agroclimatic parameters and also a method which can disseminate information quickly.

REFERENCES

Binswanger, H.P., Jodha, N.S., Ryan, J.G., and von Oppen, M. 1977. Approach and hypotheses for the village level studies of ICRISAT. ICRISAT Economics Program occasional paper 15, Patancheru, A.P., India.

Colmenares, J.H. 1975. Adoption of hybrid seeds and fertilizers among Colombian corn growers. Ph.D. thesis, University of Wisconsin, U.S.A.

Desai, G.M. 1969. Growth of fertilizer use in Indian agriculture: past trend and future demand. Cornell International Agricultural Development Bulletin 18, Cornell University, Ithaca, U.S.A.

Desai, G.M. 1978. A critical review of fertilizer consumption after 1974-75 and prospects of future growth. Fertilizer News 23(7). Fertilizer Association of India, New Delhi, India.

Desai, G.M., Chary, P.N., and Bandhopadhyay, S.C. 1973. Dynamics of growth in fertilizer use at micro-level. CMA, Indian Institute of Management (IIM), Ahmedabad, India.

Desai, G.M., and Singh, Gurdev. 1973. Growth of fertilizer use in districts of India: performance and policy implications. CMA, Indian Institute of Management (IIM), Ahmedabad, India.

Jayaraman, T.K. 1979. Fertilizer consumption in Gujarat State: an inter-district analysis. Fertilizer News 24(11). Fertilizer Association of India, New Delhi, India.

Jha, Dayanatha. 1980. Fertilizer use and its determinants: a review with special reference to semi-arid tropical India. ICRISAT Economics Program progress report 11, Patancheru, A.P., India.

Jha, Dayanatha, and Sarin, Rakesh. 1980. Fertilizer consumption and growth in semi-arid tropical India: a district level analysis. ICRISAT Economics Program progress report 10, Patancheru, A.P., India.

Jodha, N.S. 1977. Resource base as a determinant of cropping patterns. ICRISAT Economics Program occasional paper 14, Patancheru, A.P., India.

Jodha, N.S. 1979. Some dimensions of traditional farming systems in semi-arid tropical India. ICRISAT Economics Program progress report 4, Patancheru, A.P., India.

Jodha, N.S. 1979. Intercropping in traditional farming systems. ICRISAT Economics Program progress report 3, Patancheru, A.P., India.

Jodha, N.S., Asokan, M., and Ryan, J.G. 1977. Village study methodology and resource endowments of selected villages. ICRISAT Economics Program occasional paper 16, Patancheru, A.P., India.

Krishnaswamy, M.S., and Patel, K.V. 1973. Status of dryland agriculture (the technology of dryland agriculture in selected villages of Bellary and Panchmahals districts: 1970-71). Indian Institute of Management. Vol. I, CMA, Ahmedabad, India.

Maharaja, M.H. 1975. Demand for fertilizers. Good Companions, Baroda, India.

NCAER. 1974. Fertilizer use on selected crops in India. National Council of Applied Economic Research, New Delhi, India.

NCAER. 1978. Interim report: fertilizer demand survey. National Council of Applied Economic Research. Vols. 1-6, New Delhi, India.

Sahrawat, K.L., Rego, T.J., and Burford, J.R. 1979. Work experience in rainfed farming systems at ICRISAT with special reference to fertilizer use. Presented at Group Discussion on Fertilizer Use on Drylands, Fertilizer Association of India, New Delhi, India.

Sohbati, G.K. 1979. Role of fertilizer industry in fertilizer promotion. Fertilizer News 24(4). Fertilizer Association of India, New Delhi, India.

Umrani, N.K. 1979. Research achievements with special reference to fertilizer use in drylands: suggestions, field experience to solve them in Maharashtra. Presented at the Group Discussion on Fertilizer Use on Drylands, Fertilizer Association of India, New Delhi, India.

Venkateswarlu, J. 1979. Dryland agriculture — concepts and results in prospect and retrospect with special reference to fertilizer use. Presented at the Group Discussion on Fertilizer Use on Drylands, Fertilizer Association of India, New Delhi, India.

Vijayalakshmi, K. 1979. Research achievements with special reference to fertilizer use in drylands, Andhra Pradesh. Presented at the Group Discussion on Fertilizer Use on Drylands, Fertilizer Association of India, New Delhi, India.

DJ,RS:vsssm
11-11-1981

Appendix I. Salient features of selected villages in the ICRISAT Village Level Studies.

Region	District/Village	Major soil type[a]	Normal annual rainfall (mm)[a]	Major crops grown in the villages[a]	Average size of holding[b] (ha)	Percent irrigated area[b] (%)	Cropping intensity[b] (ha)	Area per family worker[a] (ha)	Area per bullock pair[a] (ha)
I	Sholapur (Maharashtra)								
	1. Kalman	Medium-deep vertisols	660	Rabi sorghum, wheat, pigeonpea, chickpea, minor pulses	8.5	10	108	2.3	13.3
	2. Shirapur	Medium-deep vertisols	636	Rabi sorghum, wheat, pigeonpea, chickpea, minor pulses	6.5	13	114	1.2	10.0
II	Akola (Maharashtra)								
	1. Kanzara	Medium-deep vertisols	819	Cotton, sorghum, mungbean, wheat, groundnut	6.5	5	103	1.1	8.0
	2. Kinkheda	Medium-deep vertisols	819	Cotton, sorghum, mungbean, wheat, groundnut	6.7	4	106	2.1	8.0
III	Mahbubnagar (Andhra Pradesh)								
	1. Aurepalle	Deep alfisols	681	Sorghum, paddy, castor, pearl millet, pigeonpea	5.6	21	114	1.3	5.0
	2. Dokur	Medium alfisols gravelly	762	Paddy, groundnut, sorghum, pigeonpea, castor	3.7	60	113	0.8	3.8

Source: a N.S. Jodha, M. Asokan, J.G. Ryan, "Village Study Methodology and Resource Endowments of the Selected Villages in ICRISAT's Village Level Studies," Occasional Paper 16, Economics Program, ICRISAT, Hyderabad, November 1977.

b N.S. Jodha, "Some Dimensions of Traditional Farming in Semi-Arid Tropical India," Progress Report 4,

Appendix II. Regressions explaining inter-farm variation in average fertilizer ($N+P_2O_5+K_2O$) use, rate of application and extent of area fertilized with nitrogenous fertilizers.

Variables	Pooled Data			Sholapur		
	AVNPK[b]	NRATE[b]	NAREA	AVNPK	NRATE	NAREA[b]
I Personal characteristics						
AGE	0.010	0.043	-0.165	-0.123	0.487	-0.238
	(0.061)[a]	(0.150)	(0.864)	(1.035)	(0.634)	(0.792)
EDUCATON	0.452	1.624	-1.259	-0.550	-3.339	-0.862
	(0.329)	(0.637)	(0.752)	(0.502)	(0.482)	(0.303)
EXPERNCE	0.728	1.196+	0.683+	-0.023	0.611	-0.141
	(1.706)	(1.513)	(1.315)	(0.057)	(0.231)	(0.139)
RISKAVER	-7.351	-0.473	-15.328*	-6.708	-60.225+	3.049
	(1.027)	(0.036)	(1.762)	(1.096)	(1.502)	(0.194)
LUCK	-0.872*	0.539	-0.226	-0.081	0.561	0.485
	(1.670)	(0.558)	(0.357)	(0.248)	(0.275)	(0.603)
II Resource endowments						
FARMSIZE	-0.725***	-0.350	-0.863***	0.026	1.266	-0.451
	(3.102)	(0.808)	(3.039)	(0.113)	(0.853)	(0.792)
IRRIGATE	0.287***	0.077	0.336***	0.095+	-0.123	0.154
	(3.823)	(0.557)	(3.706)	(1.380)	(0.307)	(0.984)
HHSIZE	0.390	1.409+	-0.783+	0.049	2.233	-0.107
	(0.864)	(1.692)	(1.439)	(0.162)	(1.123)	(0.129)
III Institutional factors						
COMCROPS	-0.224***	-0.266*	0.051	0.016	-0.049	-0.035
	(2.944)	(1.885)	(0.548)	(0.183)	(0.086)	(0.157)
CREDIT	0.001*	-0.9E-3	0.002*	0.7E-3	0.002	-0.4E-3
	(1.814)	(0.749)	(1.738)	(0.864)	(0.425)	(0.191)
FRTPRICE	1.875+	-9.918+	-0.655	1.231	-2.067	0.873
	(1.393)	(1.456)	(0.147)	(0.954)	(0.197)	(0.217)

Appendix II continued

Variables	Pooled Data			Sholapur		
	AVNPK[b]	NRATE[b]	NAREA	AVNPK	NRATE	NAREA
IV Agroclimatic factors						
RAIN	0.071**	0.078+	0.111*	0.134+	-0.111	+0.493
	(2.186)	(1.320)	(1.811)	(1.574)	(0.209)	(1.296)
RAINSQ	-0.1E-3***	-0.6E-3*	-0.9E-4*	-0.1E-3+	0.1E-3	-0.8E-3
	(2.817)	(1.921)	(1.816)	(1.597)	(0.208)	(1.304)
VDUMMY1(AUR)	16.318**	19.023+	11.574+	nc	nc	nc
	(2.507)	(1.509)	(1.376)			
VDUMMY2(DOK)	28.199***	32.956**	8.319	nc	nc	nc
	(3.372)	(2.064)	(0.776)			
VDUMMY3(KIN)	30.501***	16.279	27.227***	nc	nc	nc
	(3.645)	(1.063)	(2.737)			
VDUMMY4(KAZ)	27.596***	9.306	33.055***	nc	nc	nc
	(3.662)	(0.664)	(3.598)			
VDUMMY5(KAL)	2.494	-6.922	3.087	nc	nc	nc
	(0.364)	(0.546)	(0.364)			
YRDUMMY1(75-76)	-18.325***	-0.888	-8.934*	2.022	8.868	-24.771
	(4.186)	(0.103)	(1.661)	(0.205)	(0.136)	(0.899)
YRDUMMY2(76-77)	-13.241***	-1.700	-4.134	-2.385	11.236	-19.688+
	(3.627)	(0.240)	(0.898)	(0.693)	(0.482)	(1.527)
Intercept	-4.642	50.097	6.829	-22.459	44.587	-20.260
R^2	0.574	0.330	0.394	0.450	0.199	0.284
n	186	186	186	42	42	42

Appendix II continued

Variables	Akola			Mahbubnagar		
	AVNPK	NRATE	NAREA	AVNPK[b]	NRATE[b]	NAREA
I Personal characteristics						
AGE	0.113	-0.084	-0.375	-0.003	0.161	0.119
	(0.693)	(0.196)	(0.809)	(0.009)	(0.265)	(0.477)
EDUCATON	1.445	-0.227	-0.035	0.973	6.284	-1.129
	(1.259)	(0.074)	(0.010)	(0.253)	(1.012)	(0.420)
EXPERNCE	0.269	0.756	0.685	0.924	0.647	0.743
	(0.534)	(0.572)	(0.479)	(1.110)	(0.458)	(1.203)
RISKAVER	4.330	3.877	-1.094	-16.310	19.816	-27.201**
	(0.757)	(0.250)	(0.065)	(0.867)	(0.661)	(2.072)
LUCK	-0.494	0.427	-0.137	-1.914+	0.566	-1.318+
	(1.051)	(0.337)	(0.099)	(1.501)	(0.273)	(1.448)
II Resource endowments						
FARMSIZE	-0.433**	0.123	-0.768+	-1.348**	-0.669	-0.886**
	(2.253)	(0.239)	(1.380)	(2.296)	(0.704)	(2.167)
IRRIGATE	0.320***	0.376*	0.268	0.370**	-0.268	0.511***
	(4.228)	(1.880)	(1.237)	(2.087)	(0.899)	(3.921)
HHSIZE	-0.453	0.860	-1.674+	1.417+	1.933	-0.414
	(1.090)	(0.775)	(1.392)	(1.302)	(1.104)	(0.545)
III Institutional factors						
COMCROPS	0.038	-0.123	0.552***	-0.463**	-0.351	-0.355***
	(0.616)	(0.746)	(2.922)	(2.483)	(1.167)	(2.714)
CREDIT	0.001	0.3E-3	0.001	0.001	-0.9E-3	0.002*
	(1.064)	(0.105)	(0.372)	(1.015)	(0.452)	(1.670)
FRTPRICE	4.885***	-13.033	4.265	-0.221	-54.212**	-1.521
	(4.055)	(1.051)	(0.317)	(0.074)	(2.339)	(0.149)

Appendix II continued

	Akola			Mahbubnagar		
	AVNPK	NRATE	NAREA	AVNPK[b]	NRATE[b]	NAREA
IV Agroclimatic factors						
RAIN	0.057	0.032	0.266	0.051	0.239*	-0.002
	(0.823)	(0.168)	(1.275)	(0.576)	(1.750)	(0.021)
RAINSQ	-0.2E-5	0.3E-4	-0.1E-3	-0.7E-4	-0.2E-3*	-0.3E-4
	(0.048)	(0.270)	(0.764)	(0.796)	(1.653)	(0.305)
YRDUMMY1 (75-76)	26.287*	61.513+	74.254+	-28.784**	45.029+	-26.723***
	(1.739)	(1.431)	(1.594)	(2.096)	(1.616)	(2.839)
YRDUMMY2 (76-77)	11.451*	27.432+	28.844+	-17.020	-3.881	-3.335
	(1.660)	(1.482)	(1.439)	(1.127)	(0.160)	(0.464)
Intercept	-61.873	5.807	-141.698	28.166	214.366	60.472
R^2	0.628	0.206	0.385	0.559	0.306	0.583
n	70	70	70	74	74	74

a Figures in parentheses are t-values.

+, *, **, *** significant at 20, 10, 5 and 1% probability level, respectively.

nc. Not considered

b Rainfall during June to August has been considered in these equations.

Appendix III. Regressions explaining inter-plot variation in rates of fertilizer application.

Variables	Pooled Data		Sholapur	
	AVNPK[b]	NRATE	AVNPK	NRATE[b]
I Personal characteristics				
AGE	0.045	0.642*	0.020	0.378
	(1.038)[a]	(1.851)	(0.015)	(0.436)
EDUCATON	6.596*	5.905**	1.314	2.416
	(1.797)	(2.012)	(0.119)	(0.331)
EXPERNCE	2.556**	1.837**	0.984	2.042
	(2.279)	(2.063)	(0.211)	(0.695)
RISKAVER	8.214	7.748	-78.784+	-56.189*
	(0.455)	(0.538)	(1.522)	(1.774)
LUCK	0.410	0.925	-2.151	-1.174
	(0.308)	(0.872)	(0.642)	(0.500)
II Resource endowments				
FARMSIZE	-0.482**	-0.340*	1.119	1.270+
	(2.081)	(1.851)	(0.965)	(1.356)
HHSIZE	2.719**	2.028**	1.818	1.078
	(2.353)	(2.207)	(0.536)	(0.470)
III Plot characteristics				
SOILDMY1	21.283	12.711	-26.290	-11.380
	(1.183)	(0.890)	(0.483)	(0.326)
SOILDMY2	23.110*	7.718	-22.270	-39.341+
	(1.945)	(0.813)	(0.556)	(1.573)
IRRGDMY	45.995***	31.737***	35.344*	30.485**
	(4.145)	(3.583)	(1.651)	(2.235)
PURECROP	23.961**	15.762*	13.995	19.267
	(2.024)	(1.680)	(0.554)	(1.229)
OWNPLOT	-2.164	-0.559	D	D
	(0.138)	(0.045)		
HYVDMY	6.403	8.083	-19.543	-13.232
	(0.643)	(1.021)	(0.389)	(0.427)
IV Institutional factors				
COMCROPS	-0.399+	-0.371**	0.342	0.327
	(1.552)	(2.169)	(0.245)	(0.344)
CREDIT	0.3E-3	-0.6E-3	0.007	0.007
	(0.182)	(0.562)	(0.789)	(0.231)
FRTPRICE	1.526	-38.292***	3.980	20.383
	(0.386)	(3.620)	(0.321)	(0.648)
PRDPRICE	0.027	0.002	D	D
	(0.482)	(0.041)		

Appendix III continued

Variables	Pooled Data		Sholapur	
	AVNPK[b]	NRATE	AVNPK	NRATE[b]
V Agroclimatic factors				
RAIN	0.243***	0.094	0.702	-0.947
	(2.853)	(0.865)	(0.615)	(0.900)
RAINSQ	-0.3E-3***	-0.1E-3+	-0.6E-3	0.001
	(3.496)	(1.286)	(0.628)	(0.784)
VDUMMY1(AUR)	29.357+	17.056	nc	nc
	(1.375)	(0.993)		
VDUMMY2(DOK)	28.541	33.008*	nc	nc
	(1.144)	(1.657)		
VDUMMY3(KIN)	60.955**	42.472**	nc	nc
	(2.336)	(2.095)		
VDUMMY4(KAZ)	57.738**	50.306***	nc	nc
	(2.428)	(2.691)		
VDUMMY5(KAL)	39.042*	12.259	nc	nc
	(1.836)	(0.741)		
YRDUMMY1(75-76)	-4.068	16.920*	35.233	76.731
	(0.356)	(1.779)	(0.388)	(1.160)
YRDUMMY2(76-77)	-16.323*	4.564	5.403	32.817
	(1.761)	(0.620)	(0.141)	(1.099)
Intercept	-133.112	61.188	-167.176	-3.171
R^2	0.198	0.205	0.146	0.222
n	591	591	105	105

Appendix III continued

Variables	Akola		Mahbubnagar	
	AVNPK	NRATE	AVNPK[b]	NRATE[b]
I Personal characteristics				
AGE	0.600	0.079	0.187	0.783
	(0.941)	(0.171)	(0.236)	(1.142)
EDUCATON	0.475	-1.208	13.676*	12.791
	(0.113)	(0.392)	(1.666)	(1.864)
EXPERNCE	3.088*	2.584**	3.268*	1.882
	(1.879)	(2.209)	(1.778)	(1.203)
RISKAVER	-16.415	-16.028	66.811*	41.159+
	(0.724)	(0.970)	(1.820)	(1.287)
LUCK	-2.263+	-1.437	1.531	0.527
	(1.404)	(1.225)	(0.551)	(0.220)
II Resource endowments				
FARMSIZE	-0.274	-0.105	-0.393	-0.308
	(1.141)	(0.596)	(0.769)	(0.708)
HHSIZE	2.523+	1.729+	3.257+	2.239
	(1.617)	(1.522)	(1.497)	(1.217)
III Plot characteristics				
SOILDMY1	66.583+	62.646*	-9.547	-0.485
	(1.449)	(1.861)	(0.276)	(0.017)
SOILDMY2	61.497+	53.452+	29.636*	13.680
	(1.377)	(1.634)	(1.795)	(0.975)
IRRGDMY	65.511***	43.324***	27.478	10.563
	(5.857)	(5.320)	(0.852)	(0.371)
PURECROP	29.813***	21.680***	-80.263	-53.000
	(2.933)	(2.929)	(0.724)	(0.569)
OWNPLOT	11.589	4.819	1.934	8.495
	(0.597)	(0.334)	(0.084)	(0.433)
HYVDMY	0.641	0.638	7.249	14.259
	(0.064)	(0.089)	(0.418)	(0.972)
IV Institutional factors				
COMCROPS	-0.230	-0.225+	-0.738*	-0.701**
	(1.000)	(1.328)	(1.821)	(2.100)
CREDIT	-0.001	-0.002	0.002	0.7E-3
	(0.461)	(0.800)	(1.063)	(0.416)
FRTPRICE	5.867	-18.043+	2.433	-64.815**
	(1.108)	(1.285)	(0.337)	(2.460)
PRDPRICE	D	D	D	D

Appendix III continued

Variables	Akola		Mahbubnagar	
	AVNPK	NRATE	AVNPK	NRATE
V Agroclimatic factors				
RAIN	-0.035	-0.012	0.266	0.186
	(0.124)	(0.054)	(1.271)	(1.163)
RAINSQ	-0.6E-4	-0.6E-4	-0.4E-3**	-0.2E-3+
	(0.311)	(0.416)	(2.098)	(1.592)
YRDUMMY1(75-76)	-35.767	-12.024	-23.169	39.395+
	(0.582)	(0.250)	(0.778)	(1.351)
YRDUMMY2(76-77)	-14.344	-6.946	13.182	25.365
	(0.537)	(0.348)	(0.444)	(1.006)
Intercept	-24.751	75.460	-24.059	221.273
R^2	0.356	0.328	0.163	0.159
n	208	208	278	278

a Figures in parentheses are t-values.

+, *, **, *** significant at 20, 10, 5 and 1% probability levels.

D. Variable excluded because of dependency problem.

nc. Not considered

b In these equations, rainfall during June to August has been considered.

Appendix IV. Regressions explaining inter-farm variation in rate of application and extent of area manured

Variables	Pooled Data		Sholapur		Akola		Mahbubnagar	
	OMRATE	OMAREA	OMRATE	OMAREA	OMRATE	OMAREA	OMRATE	OMAREA
I Personal characteristics								
AGE	0.360	0.279*	1.183	-0.066	0.264	0.807**	0.633	0.255
	(0.680)[a]	(1.748)	(0.852)	(0.570)	(1.029)	(2.061)	(0.557)	(1.162)
EDUCATON	3.475	1.345	4.771	-0.194	1.709	3.003	13.797	3.472+
	(0.764)	(0.980)	(0.410)	(0.199)	(0.914)	(1.052)	(1.166)	(1.518)
EXPERNCE	0.749	0.618+	1.768	-0.144	1.299*	1.449	0.562	0.233
	(0.525)	(1.436)	(0.421)	(0.411)	(1.649)	(1.206)	(0.250)	(0.535)
RISKAVER	19.612	8.300	60.145	1.828	-5.277	23.437*	67.717	-8.467
	(0.812)	(1.151)	(0.865)	(0.314)	(0.566)	(1.649)	(1.121)	(0.725)
LUCK	0.756	0.236	4.038	-0.154	-0.535	2.402**	1.102	-1.320+
	(0.425)	(0.440)	(1.078)	(0.491)	(0.666)	(1.960)	(0.252)	(1.560)
II Farm resource endowments								
FARMSIZE	0.844	-0.519**	4.235+	-0.420*	-0.166	-0.963**	2.149	-0.555+
	(1.064)	(2.171)	(1.439)	(1.706)	(0.534)	(2.034)	(1.215)	(1.624)
IRRIGATE	0.598**	0.008	0.001	0.006	0.124	-0.219	0.929**	0.069
	(2.406)	(0.111)	(0.002)	(0.106)	(1.024)	(1.184)	(1.980)	(0.756)
HHSIZE	0.032	-0.370	0.938	0.403+	0.425	0.210	-0.244	-0.987+
	(0.022)	(0.828)	(0.283)	(1.454)	(0.643)	(0.208)	(0.069)	(1.447)
LIVESTOK	21.490*	9.083***	27.677	-1.020	14.349*	32.868**	20.772	6.926*
	(1.891)	(2.653)	(0.502)	(0.221)	(1.674)	(2.513)	(1.115)	(1.924)
III Institutional factors								
COMCROPS	-0.070	0.042	0.878	0.229***	-0.080	-0.235+	-0.457	0.118
	(0.276)	(0.552)	(0.862)	(2.688)	(0.789)	(1.517)	(0.754)	(1.008)
CREDIT	0.002	-0.0001	-0.006	-0.3E-3	-0.6E-3	-0.003	0.005	0.3E-3
	(1.043)	(0.153)	(0.664)	(0.384)	(0.387)	(1.039)	(1.243)	(0.387)

Appendix IV continued

Variables	Pooled Data		Sholapur		Akola		Mahbubnagar	
	OMRATE	OMAREA	OMRATE	OMAREA	OMRATE	OMAREA	OMRATE	OMAREA
IV Agroclimatic factors								
VDUMMY1 (AUR)	-4.718	3.410	nc	nc	nc	nc	nc	nc
	(0.220)	(0.528)						
VDUMMY2 (DOK)	-7.859	-0.938	nc	nc	nc	nc	nc	nc
	(0.291)	(0.115)						
VDUMMY3 (KIN)	-30.365	13.748*	nc	nc	nc	nc	nc	nc
	(1.195)	(1.796)						
VDUMMY4 (KAZ)	-23.080	8.503	nc	nc	nc	nc	nc	nc
	(0.989)	(1.209)						
VDUMMY5 (KAL)	-1.502	-6.202	nc	nc	nc	nc	nc	nc
	(0.068)	(0.930)						
YRDUMMY1 (75-76)	8.053	14.520	24.814	2.569	20.547***	36.173***	6.055	5.917
	(0.643)	(3.345)	(0.619)	(0.767)	(3.683)	(4.250)	(0.224)	(1.131)
YRDUMMY2 (76-77)	23.851**	12.115	60.408+	-0.409	15.384***	29.220	37.356+	8.242+
	(2.026)	(3.415)	(1.614)	(0.139)	(2.779)	(3.459)	(1.429)	(1.632)
Intercept	-27.473	-18.762	-133.538	7.078	-22.031	-45.295	-106.597	-2.346
R^2	0.254	0.263	0.453	0.724	0.618	0.641	0.446	0.565
n	186	186	42	42	70	70	74	74

a Figures in parentheses are t-values.
+, *, **, *** Significant at 20, 10, 5 and 1% probability level
nc. Not considered

Appendix V. Regressions explaining inter-plot and inter-farm variation in rate of application of manures

Variables	Pooled Data OMRATE	Sholapur OMRATE	Akola OMRATE	Mahbubnagar OMRATE
I Personal characteristics				
AGE	-0.074	1.747*	0.170	0.011
	(0.255)[a]	(1.690)	(1.232)	(0.021)
EDUCATON	0.107	-4.908	0.355	5.235
	(0.043)	(0.647)	(0.359)	(1.051)
EXPERNCE	0.474	2.651	0.297	0.045
	(0.630)	(0.754)	(0.851)	(0.048)
RISKAVER	14.833	2.274	2.662	41.353*
	(1.227)	(0.062)	(0.515)	(1.648)
LUCK	0.659	3.369+	0.123	0.021
	(0.726)	(1.336)	(0.310)	(0.011)
II Farm resource endowments				
FARMSIZE	0.774	-0.155	-0.044	0.468+
	(0.494)	(0.177)	(0.810)	(1.493)
HHSIZE	-0.215	5.510***	-0.044	-1.183
	(0.280)	(2.609)	(0.122)	(0.806)
LIVESTOK	15.044***	-38.651	9.004*	17.239**
	(2.606)	(0.972)	(1.679)	(2.130)
III Plot characteristics				
SOILDMY1	16.572	11.938	-0.678	10.099
	(1.372)	(0.280)	(0.072)	(0.434)
SOILDMY2	26.358***	28.456	4.977	23.159**
	(3.293)	(0.929)	(0.543)	(2.108)
IRRGDMY	3.713	10.696	-3.550+	16.935
	(0.498)	(0.644)	(1.460)	(0.766)
PURECROP	1.800	8.807	2.175	-33.231
	(0.227)	(0.452)	(0.971)	(0.435)
OWNPLOT	-21.319**	D	-5.169	-24.571+
	(2.005)		(1.210)	(1.542)
HYVDMY	15.928**	57.297+	1.686	27.778**
	(2.403)	(1.469)	(0.773)	(2.334)
IV Institutional factors				
COMCROPS	0.126	0.429	-0.040	0.092
	(0.864)	(0.416)	(0.775)	(0.345)
CREDIT	0.003***	-0.004	0.003	0.005***
	(3.61)	(0.523)	(0.537)	(3.624)
PRDPRICE	0.327	D	D	D
	(0.893)			

Appendix V. Continued

Variables	Pooled Data OMRATE	Sholapur OMRATE	Akola OMRATE	Mahbubnagar OMRATE
V Agroclimatic characteristics				
VDUMMY1(AUR)	-20.101+ (1.427)	nc	nc	nc
VDUMMY2(DOK)	-33.571** (2.105)	nc	nc	nc
VDUMMY3(KIN)	-44.836*** (2.708)	nc	nc	nc
VDUMMY4(KAZ)	-46.698*** (3.065)	nc	nc	nc
VDUMMY5(KAL)	-18.074+ (1.325)	nc	nc	nc
YRDUMMY1(75-76)	14.388** (2.202)	22.422 (1.053)	6.007** (2.263)	12.079 (0.975)
YRDUMMY2(76-77)	16.482*** (2.776)	23.553 (1.092)	5.656** (2.095)	23.019** (2.166)
Intercept	-21.102	-153.031	-15.731	-53.380
R^2	0.127	0.176	0.125	0.139
n	591	105	208	278

a Figures in parentheses are t-values.

+, *, **, *** Significant at 20, 10, 5, 1% probability level.

D. Variable not considered because of dependency problem.

nc Not considered.