Fertilizer Use in Semi-Arid Tropical India

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Abstract

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Research over the last decade has shown that fertilizer can increase productivity of most dryland crops in India's semi-arid tropics (SAT). District and farm data were employed to analyze levels and determinants of fertilizer use within and across regions in this area.

Profitability of fertilizer application and assurance of response were the major forces motivating fertilizer use in the Indian SAT. Average fertilizer consumption was 57 kg/ha in the irrigated and 18 kg/ha in the nonirrigated SAT districts. Farmers owning irrigated and dryland plots accorded priority to higher-response crops in allocating their scarce irrigation and cash resources. A majority of farmers used fertilizer on nonirrigated cereal high-yielding varieties, and more than 80% of them growing sorghum and pearl millet hybrids under dryland conditions in the major producing districts applied fertilizer to these crops. This suggests that it is unresponsiveness of traditional crop varieties to fertilizer application—not their low value—that inhibits fertilizer adoption.

Knowledge, represented by farmers' experience with fertilizer and education, was the most significant determinant in explaining the variation in fertilizer use among farmers within the same region. Relatively few farmers knew about specific fertilizer recommendations for dryland crops. Research and extension efforts are crucial for generating and diffusing more and better-quality information on fertilizer use on dryland crops in India's SAT.

Résumé

Jha, D. et Sarin, R. 1984. (*Utilisation des engrais dans les zones tropicales semi-arides en Inde*). Fertilizer use in semi-arid tropical India. Research Bulletin no.9. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Les recherches effectuées au cours de la dernière décennie ont révélé que l'utilisation des engrais pourrait sensiblement augmenter la productivité de la plupart des cultures sèches des zones tropicales semi-arides en Inde. Les données recueillies à l'échelle des districts ainsi que dans les champs paysans ont permis d'analyser les taux et les facteurs déterminants de l'utilisation des engrais entre les zones et à l'intérieur même de celles-ci.

Dans les zones tropicales semi-arides indiennes, c'est essentiellement la rentabilité de l'emploi d'engrais et la réponse assurée des cultures qui ont incité les paysans à utiliser des engrais. La consommation moyenne en engrais a été de 57 kg/ha dans les zones semi-arides irriguées et de 18 kg/ha dans les zones pluviales. Les paysans disposant de parcelles irriguées et pluviales ont accordé la préférence à des cultures à réponse plus élevée en ce qui concerne l'allocation de leurs ressources maigres pécuniaires et en irrigation. La plupart des paysans ont utilisé des engrais sur des variétés céréalières pluviales à haut rendement; ainsi, plus de 80% d'entre eux suivant la culture des hybrides dans les conditions sèches dans les régions principales du sorgho et du mil, ont eu recours à l'application des engrais.

Ceci donne à croire que, contrairement à leur faible valeur, c'est le manque de réponses à l'emploi des engrais des variétés traditionnelles qui constitue l'obstacle principal à l'adoption des engrais.

Les connaissances, représentées par l'éducation des paysans ainsi que leur expérience avec des engrais, ont constitué le facteur déterminant le plus important expliquant la variation de l'utilisation d'engrais parmi les paysans d'une même région. Relativement peu de paysans ont été sensibles aux préconisations particulières d'emploi des engrais pour les cultures sèches. Les travaux de recherche et de vulgarisation sont primordiaux dans l'élaboration et la diffusion de davantage d'informations de qualité supérieure sur l'emploi des engrais sur les cultures sèches dans les zones tropicales semi-arides en Inde.

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Acknowledgements

This report summarizes the results of our efforts to understand fertilizer use in SAT India. Most of the material presented here has been taken from our earlier reports (listed below); we have attempted to consolidate the findings.

JHA, D. 1980. Fertilizer use and its determinants: a review with special reference to semi-arid tropical India. ICRISAT Economics Program Progress Report no. 11 (unpublished).

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JHA, D., and SARIN, R. 1980. Fertilizer consumption and growth in semi-arid tropical India: a district-level analysis. ICRISAT Economics Program Progress Report no. 10 (unpublished).

JHA, D., and SARIN, R. 1981. An analysis of levels, patterns and determinants of fertilizer use on farms in selected regions of semi-arid tropical India. ICRISAT Economics Program Progress Report no. 25 (unpublished).

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Introduction

Fertilizer use in Indian agriculture is relatively recent. Prior to the 1940s, it was negligible and confined to commercial crops. The imperative need to increase food production rapidly, first realized in the Grow More Pood Campaign days (1942) and persisting through the following years, led to active state intervention and gave a boost to programs for extension of fertilizer use on food crops. However, in 1965-66, despite nearly two decades' effort, the average level of fertilizer (total plant nutrients) use stood well below 5 kg/ha of cropped area.

The "new strategy for agricultural development," initiated in the mid-1960s, had high-yielding varieties (HYV)* and fertilizers as its key components. It envisaged massive imports as well as expansion of domestic fertilizer-production capacity. In the years that followed, despite a spell of stagnation in the early 1970s and the price hike in 1974, the average consumption of fertilizers (NPK) per hectare of cropped area rose substantially, and currently (1978-79) stands at about 30 kg/ha. Moreover, food crops now claim a significant share of total fertilizers used in the country.

The green revolution and its equalizing impact focused attention on the spatial and crop base of fertilizer use in the country. An analysis covering 286 districts (Desai and Singh 1973) showed that more than 80% of nitrogen and phosphorus was consumed in less than one-third of those districts in 1968-69, most of which had well-developed irrigation resources. At the other extreme, over 50% of the districts consumed only 10% of the total fertilizer used.

A number of studies (Desai and Singh 1973, Desai et al. 1973, Desai 1969, and NCAER 1974) showed that irrigated crops overwhelmingly dominated fertilizer consumption. There was also evidence that, among nonirrigated crops, only some commercial crops such as cotton, tobacco, chillies, and groundnut receive some fertilizer. The recent NCAER (National Council of Applied Economic Research) survey (NCAER 1978) revealed that among nonirrigated food crops, only the HYV of sorghum and millets—in areas where they have adapted well—are fertilized, but the major fraction of rainfed food-crop area goes largely unfertilized.

These facts and other evidence on growing disparities between irrigated and nonirrigated areas highlighted the urgent need to direct developmental and research efforts to dry areas and nonirrigated cropping systems. Accordingly, the early 1970s witnessed a substantial strengthening of research on dryland agriculture, initiation of special programs for drought-prone areas, and larger allocation of developmental resources for such areas.

Nearly two-thirds of India's cropped land falls in the semi-arid zone, of which less than one-third has well-developed irrigation resources.[1] The latter, spread over the northern Indo-Gangetic plains and the coastal areas of Tamil Nadu and Andhra Pradesh, form the heartland of the green revolution, with high intensities of fertilizer use (Desai and Singh 1973). The nonirrigated semi-arid tropics (SAT) cover nearly 42% of India's cropped area and 65% of that in the Indian SAT. These are spread mainly over Madhya Pradesh, Maharashtra, Gujarat, eastern Rajasthan, central Andhra Pradesh, and Karnataka. This vast region, characterized by low output and highly unstable agricultural systems supporting fairly high population densities (Bapna et al. 1979), poses the

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*This widely-accepted term and its abbreviation are used in this bulletin to include both hybrids and varieties of self- and cross-pollinated crops, developed as improved cultivars for farmers[1] use in the semi-arid tropics.

[1] See Chapter I.

greatest challenge. Until recently, these were looked upon as problem areas requiring relief and protection rather than as areas capable of making a positive contribution to India's agricultural growth.

Research over the last decade has revealed that the productivity of most dryland crops could be raised significantly through improved soil and water management, appropriate fertilization and agronomic adjustments, and superior varieties.[2] Efficient soil fertility and moisture management, coupled with appropriate varietal choice have been identified as the key factors. Successful transfer of these improved technologies requires a clear understanding of existing dryland farming systems, farmers' response to innovations, and technological and socioeconomic factors inhibiting the adoption and diffusion process.

This monograph reports the results of a project on fertilizer use in semi-arid tropical India. As indicated above, fertilizer constitutes an important component of the prospective technologies for development of SAT agriculture. Most past studies on fertilizer use have focused on irrigated areas and crops perhaps because, traditionally, fertilizers have been used very little for nonirrigated crops. There is some evidence to show that this pattern is changing and that some fertilizers are being used for nonirrigated crops (other than high-value commercial crops). It is important to evaluate these changes to assess the technological possibilities in semi-arid agriculture. We also need to understand what factors determine SAT farmers' decisions on fertilizer use. These issues are investigated in this report.

Attention is also focused on the use of fertilizers for high-yielding varieties of sorghum and pearl millet—the major cereals grown on drylands in SAT India. High-yielding varieties form the most important component of the strategy to improve food production in these areas. The spread of these varieties has been low and selective because of several technological and socioeconomic factors. However, these are outside the scope of this enquiry which seeks to provide information on the extent and level of fertilizer use observed on farmers' fields. This information is valuable in sorghum and pearl millet crop improvement and management research.

Two basic hypotheses run through the report: first, that farmers' decisions on fertilizer allocation are based mainly on the size and certainty of returns from fertilizer use, indicated in the historical emphasis on irrigated and high-value commercial crops; second, that SAT farmers are not traditionally averse to adoption of fertilizers. The pattern of low fertilizer use is seen to be related more to the returns expected than to agroclimatic, technological, or other constraints.

This report focuses specifically on the following issues:

1. How much fertilizer is currently consumed in irrigated and nonirrigated SAT regions of the country.

2. What has been the growth pattern in consumption of fertilizers in these areas.

3. How SAT farmers allocate fertilizers between crops.

4. What are the fertilization practices of farmers in terms of rate of application, extent of area fertilized, use of organic manures, timing of application, use of different nutrients, awareness, etc.

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[2] ICRISAT 1981.

5. **What are the major determinants of fertilizer use in SAT agriculture.**

Chapter I provides an overview of fertilizer consumption in SAT India, based on analysis of district-level data. Chapter II—the main part of this report—focuses on fertilizer-use patterns on farms in three agroclimatic zones in peninsular India; it is based on data collected from six villages under the Village-Level Studies being conducted by ICRISAT since 1975. Chapter III presents an analysis of data on fertilizer use for high-yielding varieties of sorghum and pearl millet. This is based on farm-level data from 47 selected districts collected by the Indian Agricultural Statistics Research Institute, New Delhi. Chapter IV presents the results of regression-based models on determinants of fertilizer use based on those two data sets. The main implications for agricultural research, extension, and development programs arising from these analyses are discussed in the final chapter.

1. Fertilizer Consumption in Semi-Arid Tropical India: District-Level Analysis

This chapter provides an overview of fertilizer consumption in semi-arid tropical (SAT) India, with specific emphasis on:

1. How much fertilizer is actually used in the irrigated and nonirrigated areas of SAT India.
2. Whether fertilizer use is uniformly spread over the entire SAT region.
3. What has been the pattern of growth in fertilizer consumption over the last decade: 1969-70 to 1978-79.
4. Whether the data for the 1970s indicate any slackening of demand for fertilizers in the irrigated SAT areas.

Data and Methodology

This analysis is based on district-level data. The Indian SAT is spread over 10 states: Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Punjab, Haryana, Rajasthan, and Gujarat. Based on normal annual rainfall, 192 districts belonging to these 10 states have been classified as SAT districts.[3] Of these, 78 have well-developed irrigation and the rest are primarily nonirrigated.

Data on fertilizer consumption in these districts were taken from Fertilizer Statistics 1978-79, an annual publication of the Fertilizer Association of India, New Delhi. Current fertilizer consumption estimates were worked out by taking the average consumption of nitrogen (N), phosphorus (P_2O_5), and potash (K_2O) per hectare of cropped area in each of these districts during 1977-78 and 1978-79.[4] The estimates are given in kilograms. For the analysis of

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[3] See Bapna et al. 1979 for details of this classification.

[4] The use of oxide units was preferred because districtwise consumption data were available consistently in these units. The term "fertilizer" has been used in its nutrient connotation.

growth in fertilizer use, consumption levels in the initial period (average of 1969-70 and 1970-71) and the current period (average of 1977-78 and 1978-79) were compared, and the increment (or change) expressed in annual terms as the linear growth rate.

Fertilizer Consumption

Table 1 shows the average level of fertilizer (nutrient) consumption in kg/ha of gross cropped area in the SAT as a whole, and in irrigated and nonirrigated zones. The average fertilizer-consumption levels in the SAT districts are a little higher than the corresponding national averages, but the figures for the irrigated and nonirrigated zones reveal the wide variation in fertilizer consumption within the SAT. The average level of consumption of $N+P_2O_5+K_2O$ in the irrigated SAT districts is over three times as high as in the .nonirrigated districts. Among individual nutrients, the gap is more pronounced in nitrogen consumption. As Table 1 shows, the average consumption ratio of N, P_2O_5 ,and K_2O is less heavily biased towards nitrogen in the nonirrigated SAT districts.

Table 1. Average level of fertilizer consumption in kg/ha of gross cropped area (1977-79).

Fertilizer	Irrigated SAT (78 dists)	Nonirrigated SAT (114 dists)	Total SAT (192 dists)	All-India
Nitrogen (N)	40.0 (6.8)	11.6 (4.8)	21.5	18.9
Phosphorus (P_2O_5)	11.6 (2.0)	4.5 (1.9)	7.0	5.9
Potash (K_2O)	5.9 (1.0)	2.4 (1.0)	3.6	3.2
(N+P2O5+K2O)	57.5	18.5	32.1	28.0

Figures in parentheses indicate consumption ratio of N and P_2O_5 in relation to K_2O.

The table also shows that irrigated districts are major consumers of chemical fertilizers in SAT India. The pattern is more clearly brought out in Table 2 which shows the proportion of aggregate fertilizer consumption accounted for by irrigated and nonirrigated SAT zones over two different periods—1969-70 to 1970-71, and 1977-78 to 1978-79.

The irrigated SAT districts cover only 23% of the national and about 35% of the SAT gross cropped area, but they have a 45% share in the national fertilizer consumption and 62% in the SAT. The nonirrigated districts, spread across 42% of the national and 65% of the SAT cropped area, account for a mere 27% of the national and 38% of the SAT fertilizer consumption.

Corresponding figures for 1969-71 show that the share of the irrigated areas in total SAT consumption of the three nutrients was even higher. This implies that fertilizer consumption in the nonirrigated SAT areas has improved over the decade. Both the tables show that fertilizer consumption in nonirrigated SAT areas is poor. This trend is related to the extremely low fertilization observed in most nonirrigated crops (NCAER 1978). The tables establish that irrigated areas dominate fertilizer consumption. This is why SAT regions lead in aggregate fertilizer consumption in the country, as shown in the last column of Table 2.

Table 2. Contribution of irrigated and nonirrigated SAT zones to aggregate fertilizer consumption (1977-79 and 1969-71)

Particulars	Period	Irrigated SAT	Nonirrigated SAT	Total SAT
1. Number of districts		78	114	192
2. % of all-India cropped area		23	42	65
% of SAT cropped area		35	65	-
3. % of all-India consumption:				
Nitrogen (N)	1977-79	47	26	73
	1969-71	51	24	75
Phosphorus (P_2O_5)	1977-79	43	32	75
	1969-71	47	31	78
Potash (K_2O)	1977-79	40	30	70
	1969-71	43	26	69
Total fertilizer ($N+P_2O_5+K_2O$)	1977-79	45	27	72
	1969-71	49	26	75
4. % of total SAT consumption:				
Nitrogen (N)	1977-79	65	35	na
	1969-71	68	32	
Phosphorus (P_2O_5)	1977-79	58	42	na
	1969-71	61	39	
Potash (K_2O)	1977-79	57	43	na
	1969-71	62	38	
Total fertilizer ($N+P_2O5+K_2O$)	1977-79	62	38	na
	1969-71	66	34	

na = not applicable.

The pattern of concentration in fertilizer consumption in SAT districts is presented in Table 3. Section A of this table shows the distribution of districts in terms of level of consumption of total plant nutrients per hectare of gross cropped area. The wide variation in fertilizer consumption across districts is obvious: nearly 42% of the total fertilizers consumed in the 192 districts is accounted for by 35 districts in the "above 60 kg" class. At the other extreme, 49 districts consume less than 10 kg/ha, and their share in the total fertilizer consumption is only 4.7%. Figures for irrigated and nonirrigated districts bring out this disparity more clearly. In 32 out of the 78 districts in the irrigated category, the average consumption level exceeds 60 kg/ha, and these districts account for 38.6% of the total fertilizer consumed in the SAT; in only one district is fertilizer consumption less than 10 kg/ha. On

Table 3. Distribution of SAT districts over indicated fertilizer ($N+P_2O_5+K_2O$) consumption levels (1977-79).

	Irrigated SAT			Nonirrigated SAT			Total SAT	
Consumption range[1]	No. of dis- tricts	% of total SAT con- sumption	% of irri- gated SAT consumption	No. of dis- tricts	% of total SAT con- sumption	% of non- irrigated SAT consumption	No. of dis- tricts	% of total SAT con- sumption
A.								
> 60	32	38.6	62.2	3	3.1	8.2	35	41.7
41 - 60	21	14.3	23.0	9	7.3	19.3	30	21.6
21 - 40	20	8.5	13.6	30	15.6	41.5	50	24.1
11 - 20	4	0.7	1.1	24	7.2	18.9	28	7.9
5 - 10	nil	na	na	26	3.5	9.2	26	3.5
< 5	1	0.1	0.1	22	1.1	2.9	23	1.2
Total	78	62.2	100.0	114	37.8	100.0	192	100.0
B.								
> 60	4	9.0	14.5	nil	na	na	4	9.0
41 - 60	15	20.6	33.2	2	2.5	6.6	17	23.1
31 - 40	8	8.0	12.8	7	6.9	18.3	15	14.9
21 - 30	19	13.2	21.4	14	9.5	24.8	33	22.7
11 - 20	22	9.5	15.2	28	11.8	31.3	50	21.3
5 - 10	7	1.5	2.4	23	4.5	12.1	30	6.0
< 5	3	0.4	0.5	45	2.6	6.9	43	3.0
Total	78	68.2	100.0	114	37.8	100.0	192	100.0

1. Refers to total plant nutrients used, in terms of kg/ha cropped area for section A and '000 t per district for section B.

na = not applicable.

the other hand, in only three nonirrigated districts do consumption levels exceed 60 kg/ha, while in as many as 48, they are less than 10 kg. Thus, while in nearly 68% of the irrigated districts fertilizer consumption is more than 40 kg/ha, in over 89% of the nonirrigated districts, consumption levels are below 40 kg/ha.

To facilitate comparison with other analyses, Section B of Table 3 shows the distribution in terms of fertilizer consumption per district. Statistics for the country as a whole (FAI 1979) indicate that total fertilizer ($N+P_2O_5+K_2O$) consumption in nearly 12% of the districts in the country exceeds 30 000 tonnes, and these districts account for over 42% of the national consumption. At the other extreme, 45% of the districts consume less than 5000 tonnes, and their share in the national comsumption is barely 8%. Data for all the SAT districts, presented in Table 3, reveal a similar variation among districts. Figures for irrigated and nonirrigated SAT districts reinforce the earlier conclusions. Most of the high fertilizer-consuming districts belong to the irrigated category, while low fertilizer-consuming districts come under the nonirrigated category. The distribution of all SAT districts conveys a more favorable impression when compared to the country as a whole because of the blending of these two contrasting distributions. Despite this apparent clustering, it would be incorrect to infer that there is no variation among districts within each category. For example, within the nonirrigated SAT there are 12 districts where the consumption level exceeds 40 kg/ha, and these districts account for 27.5% of the fertilizer consumption in the nonirrigated SAT; a slightly higher share is claimed by 72 districts consuming less than 20 kg/ha. Thus, even within the nonirrigated category, fertilizer consumption varies significantly and concentration tendencies persist. We hypothesize that this is largely determined by the extent of area under nonirrigated commercial crops (cotton, groundnut, tobacco, chillies, etc.).

Figure 1 shows that the districts where fertilizer consumption is low are concentrated in Madhya Pradesh, Maharashtra, Rajasthan, and Gujarat. As expected, districts where fertilizer consumption is high are concentrated in coastal Andhra Pradesh and Tamil Nadu, and in the irrigated plains of northern India. The map also shows that fertilizer consumption is relatively low in the irrigated districts of southern Uttar Pradesh, Madhya Pradesh, and Rajasthan.

Growth in Fertilizer Use

A districtwise analysis spanning the 1960s (Desai and Singh 1973), revealed that, by and large, the rainfed areas did not contribute significantly to growth in fertilizer consumption. The increase in consumption was a result of the spread of fertilizer use to (1) almost all crops grown under irrigated conditions; (2) high-yielding varieties, particularly wheat; and (3) a few commercial crops like cotton, groundnut, and tobacco grown under nonirrigated conditions. It was also found that growth in fertilizer consumption was concentrated in a few districts of the country. A recent resurvey, based on data till 1977, showed that, by and large, the same forces still continued to be important (Desai 1978). This section examines these findings in the context of SAT India with special reference to the 1970s (until 1979).

Table 4 shows the distribution of SAT districts according to the annual rate of change in fertilizer ($N+P_2O5+K_2O$) consumption per hectare of cropped area between 1970 (average of 1969-70 and 1970-71) and 1978 (average of 1977-78 and 1978-79). The table shows that the annual increments in fertilizer consumption varied widely among districts, implying large diversity in the growth performance of SAT districts. It also brings out the superior performance of irrigated SAT districts. In 83 districts, fertilizer consumption grew at more than 2 kg/ha per annum; 58 of those districts were in the

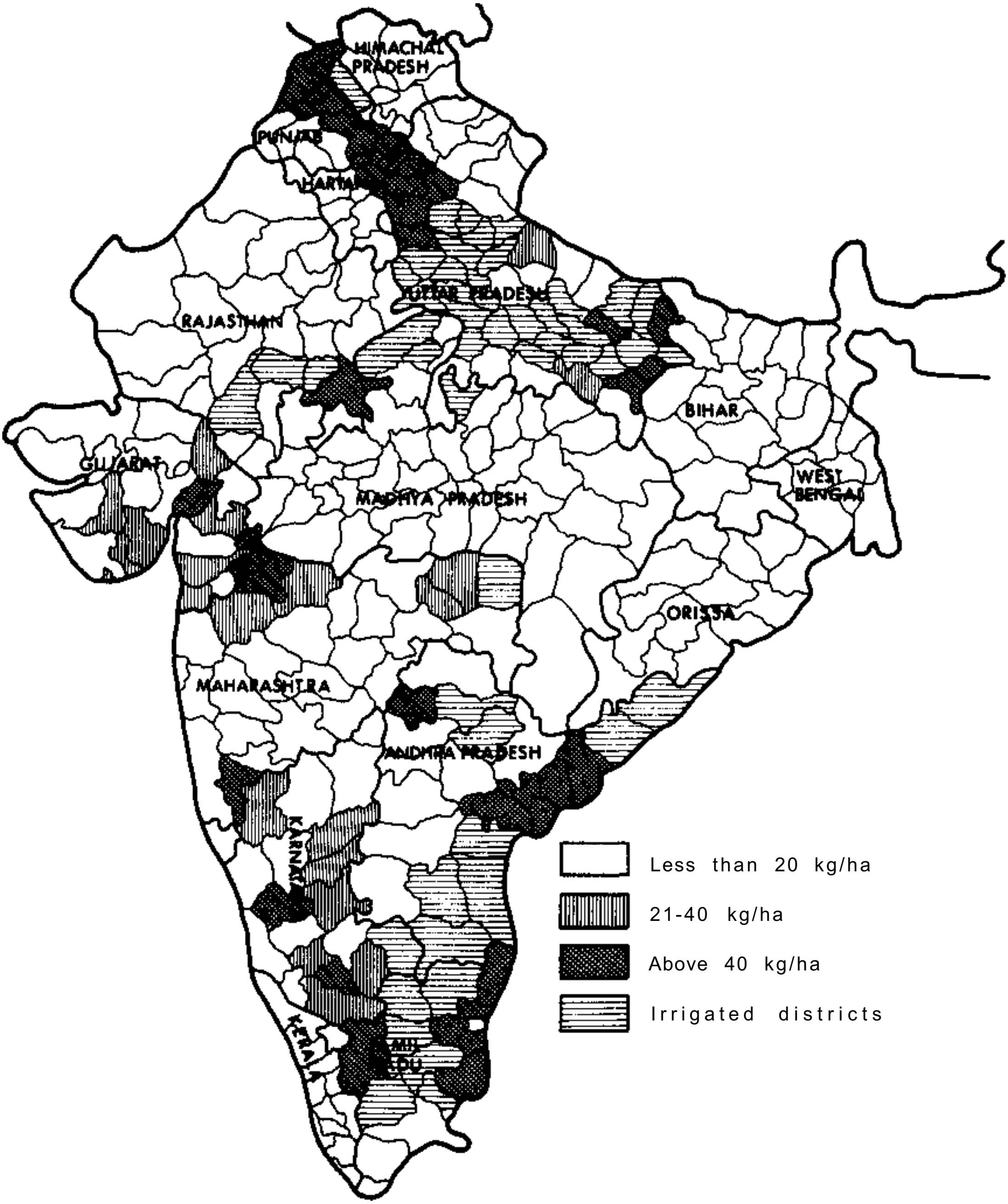

Figure 1. Average level of fertilizer ($N+P_2O5+K_2O$) consumption (kg/ha of gross cropped area) in semi-arid tropical India (1976-77).

irrigated SAT. At the other extreme, the increment rate was less than 1 kg/ha in 71 districts, 65 of which were nonirrigated. This pattern holds for nitrogen, but for phosphatic and potassic fertilizers, the irrigated districts also figured prominently in the low-growth categories,[5]

The irrigated districts have continued to perform well in terms of level of consumption (Table 3) as well as growth in consumption of fertilizers. The nonirrigated districts, with some exceptions, present a dismal picture with over one-third of them showing less than 0.5 kg/ha per annum growth in fertilizer consumption. It was also noted (data not presented here) that in the irrigated category, only 3 out of 78 districts showed less than 0.5 kg/ha growth in nitrogen consumption; 41 districts showed less than 0.5 kg/ha growth in consumption of phosphatic fertilizers; and 64 districts showed less than 0.5 kg/ha growth in potassic fertilizer consumption. This suggests that growth in nitrogen consumption is more strongly associated with irrigation (Jha 1980).

Table 4. Distribution of SAT districts according to rate of increase in fertilizer ($N+P_2O_5+K_2O$) consumption (kg/ha per annum) during 1970-78.

Rate of increase per annum (kg/ha of cropped area)	Irrigated SAT	Nonirrigated SAT	Total SAT
< 0.10	2	7	9
0.11 - 0.50	1	33	34
0.51 - 1.00	3	25	28
1.01 - 2.00	14	24	38
2.01 - 3.00	19	14	33
3.01 - 4.00	14	6	20
4.01 - 5.00	13	3	16
> 5.00	12	2	14
Total	78	114	192

The rate of growth exceeded 4 kg/ha per annum in only five nonirrigated districts. In almost all these districts, crops like cotton, groundnut, tobacco, and chillies were found to be important. Thus, despite data inadequacies, the results broadly confirm the pattern observed in the 1960s: (a) dominance of irrigated crops and areas; and (b) importance of high-value crops in nonirrigated areas (Desai and Singh 1973).

We have also evaluated the contention (Desai 1978) that, by and large, the district-level base sustaining growth in fertilizer consumption has remained quite narrow over time, by comparing the performance of high-growth districts during the 1960s and the 1970s (Appendix I). This comparison provides clear evidence of a widening of the district-level base supporting growth in fertilizer consumption. It shows that 44 irrigated and 26 nonirrigated districts experienced high growth in nitrogen consumption during the 1970s. The increase in nitrogen consumption in 25 of the irrigated districts and 5 of the nonirrigated districts was high in the 1960s as well. Similarly, in 29 irrigated and 21 nonirrigated districts, the growth in consumption of phosphatic fertilizers was high during the 1970s; in 14 of these irrigated districts and 8 of the nonirrigated, growth in consumption was high during the 1960s also. This

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5. For data, see tha and Sarin (1960).

clearly shows that new fertilizer-consuming districts have come to the fore, particularly in the nonirrigated SAT areas.

Compared with the 1960s, nitrogen and phosphorus consumption in the 1970s improved in the SAT as a whole. The irrigated districts contributed substantially to this development. In nonirrigated areas also, the percentage of districts in the high to very-high growth category showed an increase, and the percentage of districts in the low to very-low growth category recorded only a modest decline. This suggests that irrigated districts continue to provide the main base for growth in consumption of both nitrogenous and phosphatic fertilizers. Again, compared with the 1960s, many irrigated districts shifted from the low- to high-growth category in the 1970s. This was true of some nonirrigated districts as well. However, nearly half of these districts remained in the low-growth categories during the 1970s.

There was no evidence of deceleration of growth in fertilizer consumption in the irrigated areas. Appendix I, which shows the performance of high-growth districts during the 1960s and 1970s, brings this out clearly. If districts shifting from high- to low-growth categories in that period are considered as indicators of slackening fertilizer consumption, nitrogen consumption did not slacken as no districts shifted. However, with regard to phosphatic fertilizers, 4 districts (2 each in irrigated and nonirrigated categories) did shift to lower consumption levels.

The dominance of the irrigated districts is clearly brought out in Table 5, which shows the contribution of irrigated and nonirrigated SAT districts to the total growth in fertilizer consumption between 1970 and 1978.

Table 5. Contribution (%) of irrigated and nonirrigated SAT districts to growth in fertilizer consumption in SAT India (1970-78).

	Percentage of total growth	
Fertilizer	Irrigated districts	Nonirrigated districts
Total fertilizer ($N+P_2O_5+K_2O$)	59	41
Nitrogen	62	38
Phosphorus	55	44
Potash	53	47

The table shows that irrigated areas contributed the most to growth in aggregate fertilizer consumption in the SAT. This is so because nitrogen accounts for a major part of total fertilizer use, and most (62%) of the growth in nitrogen consumption is accounted for by the irrigated districts. As for growth in consumption of phosphatic and potassic fertilizers, the nonirrigated districts have contributed a relatively larger share to the post-1970 growth.

Conclusions

A study of fertilizer consumption and growth in SAT India, based on district-level data, revealed that 78 irrigated districts accounted for 62% of the total fertilizers consumed in the SAT. These districts' share of cropped area in the SAT was only 35%. The irrigated areas that show high fertilizer consumption were found to be located in the plains of northern India, and coastal Andhra Pradesh and Tamil Nadu. On the other hand, nonirrigated districts with low fertilizer consumption were spread across central and western India. The average fertilizer ($N+P_2O_5+K_2O$) consumption was 57 kg/ha of cropped area in the irrigated districts and 18 kg/ha in the nonirrigated.

The irrigated SAT districts also showed improved growth in total fertilizer consumption during 1970-78. The nonirrigated districts which did perform well were those in which nonirrigated commercial crops like cotton, groundnut, tobacco, and chillies were important.

A comparison of the growth performance of SAT districts between 1960-68 and 1970-78 revealed that the irrigated districts have continued to provide the base for growth in fertilizer consumption during the 1970s as well. Also, there was no indication of a deceleration in growth. We found no evidence for the contention that the spatial base sustaining growth in fertilizer, consumption continues to be narrow. On the contrary, our analysis shows that fertilizers were adopted in new areas, particularly nitrogenous fertilizers in nonirrigated districts. This finding has to be viewed against the following factors: (a) increase in irrigation in these so-called nonirrigated districts(the latest districtwise data on irrigation, which would help to know the exact position, are not available)[6]; (b) the cropwise base for growth in fertilizer consumption in nonirrigated areas is still narrow and remains confined to a few commercial crops; and (c) the absolute level of consumption of fertilizers continues to be below 10 kg/ha in nearly 42% of the nonirrigated districts. The fertilizer-consumption levels have, in fact, remained stagnant over the last decade in 40 out of 114 districts.

A review of past work and this analysis led to the following hypotheses:

1. Irrigated areas within SAT India continue to control growth in fertilizer consumption. Even as highly irrigated areas reach their saturation level, ongoing irrigation development efforts would lead to spread of fertilizer use to hitherto nonirrigated lands.

2. Farmers in the highly unstable SAT setting adopt fertilizers only when returns are relatively assured (as on irrigated lands) and/or high enough (as in the case of high-value commercial crops). But food-grain crops, which occupy a bulk of the nonirrigated SAT cropped area, do not respond significantly to fertilization and besides, returns on them are relatively low. While high-yielding varieties of sorghum and pearl millets have brought about some change in the situation, irrigation continues to be the key factor (NCAER 1978).

The district-level analysis does not permit testing of these hypotheses, although it reveals the magnitude of the problem and brings out the two basic motivating forces—irrigation and market incentives. The effects of technological change as a factor affecting fertilizer use can best be tested with data at the farm level.

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6. State-level data on the growth in irrigated area over this period suggest that this is a strong possibility. And even in the nonirrigated districts, a major part of the fertilizers consumed could be used on irrigated crops grown on small areas.

II. Fertilizer Use on Farms

The broad tendencies revealed by the district-level analysis stem from decisions taken by individual farmers. Hence, for a proper understanding of the pattern of fertilizer• use, it is necessary to study individual farmer behavior. This is important because it is at this level that responses to policy and other investment and technological interventions actually take place. This chapter provides information on fertilizer-use patterns and practices observed on farms in selected regions of SAT India.

Decisions governing fertilizer use are complex. First, the farmer has to decide whether to use fertilizers or not, and thereafter decide which crop(s) to fertilize and at what rate(s). Capital rationing and other factors often necessitate decision on how much cropped area to fertilize. Then follow decisions regarding how to use fertilizers, choice of fertilizer, method of application, balanced use of nutrients, etc., all of which have a bearing on the technical efficiency of fertilizer input. This chapter provides information on these aspects. A quantitative analysis of the factors which influence these decisions is attempted in Chapter IV, although even a simple description of current practices will suffice to provide some useful insights. The specific aspects discussed in this chapter are:

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

Data Source and Background of the Study Areas

Data for this analysis come from ICRISAT Village-Level Studies being conducted since 1975 in 6 villages[7]—2 each in 3 major agroclimatic zones of peninsular India.

In each of these villages, data from 40 households (10 each from landless labor, small-, medium-, and large-farm categories) were monitored by resident investigators. The salient agroclimatic and farm-resource endowment features of the selected villages are presented in Appendix II.

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) has red soils, high irrigation, low rainfall, and relatively smaller holdings. The cropping pattern is dominated by paddy.

Data on cropping pattern, fertilizer use, and other relevant aspects for the sample households[8] for 3 years (1975-76 through 1977-78) were considered. In addition, special surveys were conducted in these villages during 1979 and 1980 to obtain additional data. The results, featured in a subsequent section of this paper, are presented for regions I and II. For region III, in view of

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[7] For details see Binswanger et al. 1977.

[8] The 146 sample (farmer) households used in this study were selected on the basis that data on them were available for 3 years.

the substantial differences 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, with Sholapur and Dokur depicting extreme situations. All estimates presented in this chapter are based on 3-year averages. In all tables, fertilizer quantities have been expressed in terms of nutrients—N, P_2O_5, and K_2O—after appropriate conversion.

Adoption of Fertilizers

The first overt indicator of acceptance of an innovation is its adoption. The overall level of adoption of fertilizers will, therefore, indicate the extent to which fertilizer use has been integrated in a given farming system. Table 6 provides data on the average proportion of sample farmers using fertilizers during 1975-78.

Table 6. Proportion of farmers using fertilizer in different regions (1975-78).

			Mahbubnagar	
Particulars	Sholapur	Akola	Aurepalle	Dokur
Percentage of farmers using fertilizer[1]	29	43	38	80
Percentage of users among:				
Small farmers	14	17	0	79
Medium farmers	37	45	24	50
Large farmers	32	65	83	96
Percentage of users in:				
1975-76	31	40	33	67
1976-77	31	43	41	83
1977-78	24	47	41	89

1. Calculated by aggregating total number of farmers using fertilizer over the period of 3 years (irrespective of whether they were the same farmers or different), expressed as percentage of the total number of farmers in those 3 years.

The first row of the table shows that adoption of fertilizers was lowest in Sholapur and highest in Dokur, with Akola and Aurepalle occupying intermediate positions. The table also reveals that adoption was highest on large farms in all the three regions. These findings indicate that superior production environment (in the regional context) and higher socioeconomic status (in the interfarm context) aided higher fertilizer adoption. In Dokur, the level of adoption was quite high even on small farms. In villages other than Aurepalle, the percentage of irrigable area was higher on small farms. Differences in irrigation availability thus did not appear to be important in explaining interfarm size differences in adoption levels.

Over time, more farmers used fertilizers in 2 of the 3 regions. The exception was Sholapur which suggests its special nature.

To explore the pattern of adoption further, additional data were collected on when and on which crop the farmer started using fertilizers. The results, summarized in Figure 2, showed that fertilizer use was a relatively recent practice in the Sholapur and Akola regions; none of the farmers surveyed in these regions had used fertilizer before 1964. In Akola, adoption of fertilizers rapidly increased from 1964, but in Sholapur the process has not been so fast. In Dokur in Mahbubnagar, more than half the farmers had taken to fertilizers before 1959, and by 1978 every farmer in the village was using them. In Aurepalle, fertilizer use started in the early 1960s, but even by 1978 the cumulative percentage of fertilizer users did not go beyond 55. Fertilizer use is thus seen as an established practice in Dokur and Akola, while in the low-rainfall regions with little irrigation (Sholapur and Aurepalle), the overall adoption and rate of diffusion has been poor.

In both Aurepalle and Dokur, fertilizer use started with paddy—well before the advent of the high-yielding varieties in the mid-1960s. In the Akola region, fertilizers were first used on hybrid sorghum and cotton crops. Thus, in these two regions, availability of irrigation and/or high-response crops prompted adoption of fertilizers (Desai et al. 1973). In Sholapur, farmers started using fertilizers on a variety of crops unlike in the other regions where application was initially restricted to one or two crops. Some farmers started with irrigated crops like paddy, wheat, maize, vegetables, or sugarcane and some others chose high-response nonirrigated crops like hybrid sorghum or groundnut.[9] While the basic forces (irrigation and high-response) were apparently similar, the Sholapur situation suggested a longer phase of experimentation by farmers. This phenomenon has also been observed in another low-rainfall SAT district, Bellary in Karnataka, where fertilizer use is a recent practice (Krishnaswamy and Patel 1973) .

The picture, as presented above, reflects the pattern of first adoption, but does not provide information on continuity in farmers' use of fertilizers. Scrutiny of data collected from each individual farmer revealed that adoption was not a one-time decision for all farmers. Table 7 shows the distribution of fertilizer users over the 3-year period[10] in different categories.

Table 7. Distribution of fertilizer users according to pattern of use (1975-78).

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

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[9] Even for these nonirrigated crops, postrainy-season cropping implies assured soil moisture for adequate crop growth.

[10] 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.

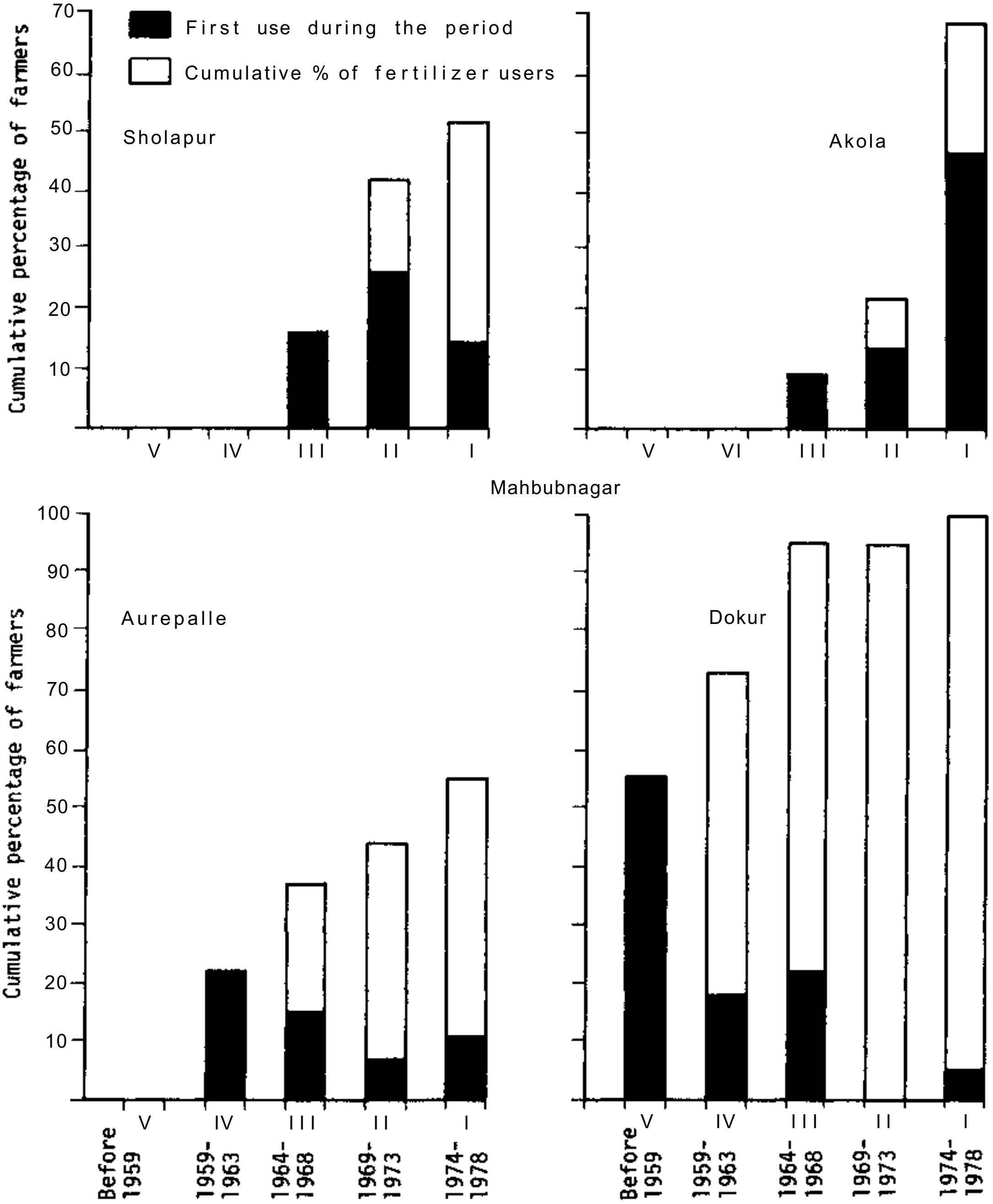

Figure 2. Adoption of fertilizer, over time, in Sholapur, Akola, and Mahbubnagar (two locations) regions.

The first two rows of Table 7 show the percentage of continuous users; and the third row, the 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. Farmers who used fertilizers only in some year(s) have been categorized under the head "others" in the table. Nearly half the fertilizer users in Sholapur belonged to this group.

Lack of irrigation and capital—not lack of awareness or apprehensions about the profitability of fertilizer use—were the main reasons for nonadoption of fertilizers. Risk was another important factor.

The comprehensive NCAER survey on fertilizer demand and a few other studies have also identified irrigation and credit as the most important constraints to wide 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, and Jha 1980). In areas with relatively high and stable rainfall and substantial area under high-value, high-response crops, fertilizer use started in the mid-1960s and has grown rather rapidly since. On the other hand, nonirrigated SAT regions with low rainfall showed low adoption levels, slow rate of diffusion, and fertilizer use was not continuous from year to year.

Levels and Variability of Fertilizer Use

Table 8 shows the average application rates and extent of area fertilized with different nutrients.

Table 8. Average level of fertilizer use on farms in different regiOns (1975-78).

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

Overall, the intensity of fertilizer use—indicated by the average level of fertilizer ($N+P_2O_5+K_2O$) consumption—was found to be very low in almost all regions except Dokur, where it was about 40 kg/ha. These figures emphasize the low level of and high interregional variation in fertilizer use in SAT areas. Table 8 also reveals that consumption was low because of the very poor extent of fertilization: only a nominal fraction of the cropped area was fertilized in Sholapur; in Akola and Aurepalle also, the percentage of area fertilized with nitrogen did not exceed one-fifth of the cropped area. Even in the highly irrigated Dokur village, not all irrigated land received fertilizer.

In all the regions, adoption levels (Table 6) were significantly higher than the percentage of areas fertilized despite the fact that farmers have been using fertilizers for 10 years or more. This indicates low diffusion of fertilizer use (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 8) were nearly twice as high in Mahbubnagar as in the Sholapur and Akola regions. Akola and Aurepalle provide an interesting comparison: the cropped area fertilized was nearly the same in both, but the rates of fertilizer (for N and P_2O_5 particularly) application were markedly different.

The interregional variation in the average parameters needs to be explained. A detailed analysis follows in Chapter IV. Table 9 provides data on the influence of irrigation on fertilizer use.

Table 9. Irrigation and fertilizer use (1975-78).

District/ village	% of cropped area irrigated	% of total fertilizer ($N+P_2O_5+K_2O$) used for irrigated crops	% of total fertilized area (with N) irrigated	Rate (kg/ha fertilized)					
				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
Hahbubnagar									
Aurepalle	21	97	91	60	32	14	14	10	2
Dokur	60	99	98	63	34	16	16	19	16

The table shows that irrigation played a dominant role in the Sholapur and Mahbubnagar regions. Irrigated crops 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 little irrigated area (less than 5%), yet more than one-third of the total fertilizer was used on irrigated crops. The data indicate that fertilizer use in the low-rainfall areas of the SAT was confined to irrigated lands. 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 the 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. Overall, the variation in the rates of fertilizer application across regions was due solely to irrigation.

Further analysis revealed that, although fertilizer use was most on irrigated lands, a significant proportion of such land received no fertilizer at all.[11] in the Mahbubnagar villages, 20-30% of the irrigated area remained unfertilized; in the Maharashtra districts, it was nearly 60%. While lack of capital and/or nonavailability of fertilizer could have been responsible for this situation in Sholapur and Mahbubnagar, the Akola case was puzzling because nonirrigated crops received a large share of the fertilizer used in this area. The existence of a fair proportion of unfertilized irrigated land was also indicated by other data sources (Jha 1980). Exploitation of this slack could lead to significant productivity gains in SAT agriculture.[12] It also follows that easing of constraints would result—at least in the Sholapur and Mahbubnagar situations—in extension of fertilizer use, initially to hitherto unfertilized irrigated land.

Allocation of Fertilizers to Crops

Several 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, and Maharaja 1975). The dominance of irrigated crops (in a low-rainfall situation), shown in the preceding section, is partial evidence in support of this finding. In this section, the subject is pursued further and attention is focused on allocation of fertilizers among different crops. The tendency noted above would imply that relatively more fertilizer-responsive crops would claim a larger share of total nutrients. Table 10 provides data on cropwise allocation of fertilizer ($N+P_2O_5+K_2O$) in different regions.

In the Mahbubnagar villages, high-yielding varieties of paddy overwhelmingly dominated the fertilizer scene. Other crops that received some fertilizer were groundnut, vegetables, and castor (in Aurepalle). No fertilizer was used for sorghum in either Aurepalle or Dokur, although this crop occupied a significant area.

The pattern observed in Sholapur—another low rainfall region—is interesting. The region is characterized by a highly subsistence-oriented cropping pattern: local varieties of sorghum and pulses account 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 fertilizer used. In sharp contrast to other regions, traditional varieties of sorghum also claimed a significant share; indeed, sorghum consumed almost the entire fertilizer used in the postrainy season.

The allocation pattern was more diverse in the Akola region. A number of crops were fertilized; cotton, wheat, sorghum, and groundnut the most important among them. The high-yielding varieties of wheat and sorghum were preferred. While wheat occupied only 2% of the gross cropped area, it accounted for nearly one-third of the total fertilizer used.

The overall pattern, presented in Table 10, thus supported the view that high-response crops claimed priority in the farmers' fertilizer-allocation

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[11] See Jha and Sarin 1981, for data.

[12] Such an effort is already under way as part of the intensive fertilizer promotion campaign in selected districts having assured irrigation but low fertilizer-consumption levels (Sohbati 1979).

Table 10. Cropwise allocation of fertilizers ($N+P_2O_5+K_2O$) on farms in selected regions (1975-78).

Crop	Sholapur		Akola		Mahbubnagar			
					Aurepalle		Dokur	
	% of gross cropped area	% of total $N+P_2O_5$ $+K_2O$	% of gross cropped area	% of total $N+P_2O_5$ $+K_2O$	% of gross cropped area	% of total $N+P_2O_5$ $+K_2O$	% of gross cropped area	% of total $N+P_2O_5$ $+K_2O$
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[2]	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[1]	1	a	a	0	6	1
Total	100	100	100	100	100	100	100	100

1. Includes maize, 6%.
2. Total of HYV and local; the HYV accounts for nearly two-thirds of the area.
a = less than 0.5.

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 the Sholapur region, although farmers did use some fertilizer for the local varieties. It should be noted that in this case also, fertilizer use was confined to the more certain postrainy season and application was restricted to the improved variety, M 35-1, which responds well to it.

Figure 3 shows the fertilizer-allocation pattern under irrigated and nonirrigated conditions separately in the Akola and Sholapur regions.[13] It was found that crops like sugarcane, paddy, wheat, and vegetables accounted for more than 80% of the total fertilizer used under irrigated conditions. Sorghum and groundnut, grown in the postrainy season, were the main nonirrigated crops fertilized in the Sholapur region.[14] Cotton, sorghum (HYV), and groundnut were the important crops in the Akola region.

The findings 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; even in such cases, farmers chose the more stable postrainy-season crop.

The crops consuming the most fertilizer were found to be those on which fertilizer was first used. This implies that in spite of having used fertilizers for 10 years or more, farmers have not extended fertilizer use to other crops, and that the crop base for fertilizer consumption continues to be narrow. Other nonirrigated (and areawise important) crops such as millets and pulses continue to be grown without any fertilizer.

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 the lack of capital and the uncertainty about soil-moisture conditions that acted as a restraint on fertilizer use in the low-rainfall region (Sholapur and Mahbubnagar). This underscores the importance of institutional credit and of technological innovations (varieties, crop-management practices), that minimize the impact of adverse soil-moisture conditions during the growth period of the crop.

Rates of Fertilizer Application

Choice of crops to be fertilized is followed by decisions regarding rates of application and the extent of cropped area to be fertilized. Table 11 presents data on these aspects for crops that consumed a significant quantity of fertilizer in different regions.

In both the Mahbubnagar villages, more than 80% of the area under paddy was fertilized at the rate of about 60-70 kg/ha N. The areas fertilized with P_2O_5 and K_2O were lower although the rates were similar (33-35 kg/ha P_2O_5 and 15-17 kg/ha 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.

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13. Estimates have not been presented for Aurepalle and Dokur because fertilizer use under nonirrigated conditions was nominal in these villages (Table 9).
14. The quantity of fertilizer used under nonirrigated conditions was very small.

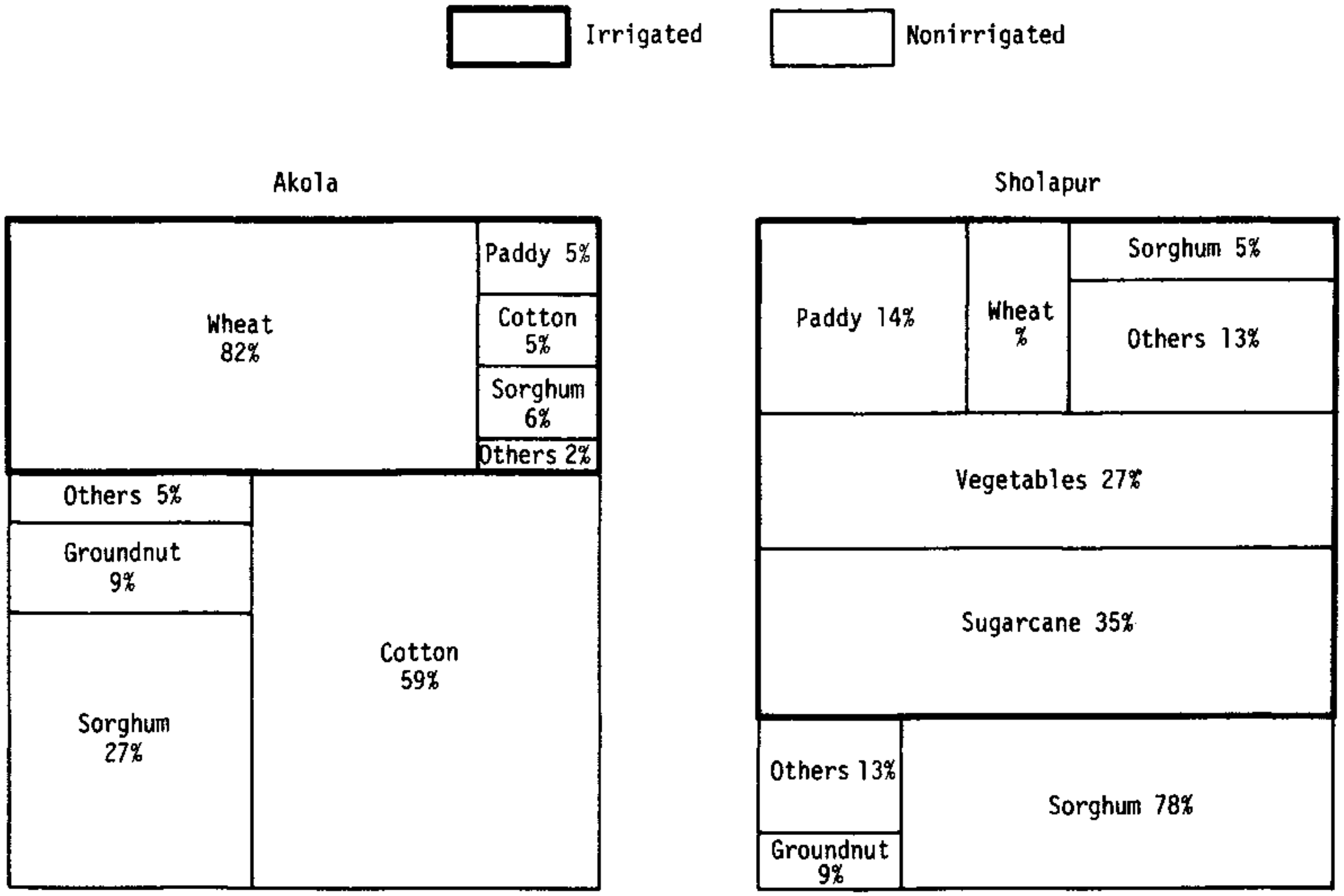

Figure 3. Allocation of fertilizers (total plant nutrients) under irrigated and nonirrigated conditions in villages in Akola and Sholapur, 1975-76 (size of the box indicates proportions of fertilizer used under irrigated and nonirrigated conditions within each district).

Table 11. Rate of application of nutrients (kg/ha fertilized), and percentage of area fertilized for indicated crops at given locations (1975-78).

							Mahbubnagar					
	Sholapur			Akola			Aurepalle			Dokur		
Crop	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)[1]	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[2] (82.6)	32.9[2] (47.3)	15.2[2] (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

1. Figures in parentheses show % of area under the crop receiving different fertilizers.
2. Values for HYV + Local. na = not applicable. nr = not reported.

In Sholapur, sugarcane and vegetables were fertilized at relatively higher levels. For all other fertilized crops, the rates of nitrogen application were in the range of 17-28 kg/ha. Nitrogen was applied on only about 30% of cropped area (with the marginal exception of paddy). The extent of areas fertilized with P_2O_5 and K_2O was very low. The table shows that only a nominal fraction of the area under local sorghum was fertilized. Table 10 shows a high percentage allocation of fertilizer to this crop only because of the high area under it, and the very low absolute level of fertilizer use in this region. It is also interesting to note that the rates of application for local and HYV of sorghum were quite similar; with respect to area fertilized, however, the HYV fared better.

The fertilizer-use values were much higher in the Akola region. In the case of HYV of wheat and cotton, more* than three-fourths of the cropped area received nitrogen and phosphorus, and more than 60% of the area received potash. In this region, significantly higher fertilizer-use parameters were observed for high-yielding varieties compared to local varieties.

In general, fertilizer-use parameters for both high-yielding and local varieties were higher for irrigated crops. The nonirrigated-crop rates (for nitrogen) were mostly below 30 kg/ha; the HYV of cotton in Akola was, however, an exception.

On comparison, the actual rates of fertilizer application were significantly lower than the recommended levels even in the highly irrigated Dokur village. This was true of almost all crops in other regions, and of the country as a whole (NCAER 1978). Inadequacy of capital and nonavailability of fertilizers might be to blame for this.15 under the circumstances, lower rates of fertilizer spread over a larger area appears 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, consequently, cease to generate further growth in effective demand for fertilizer. On the contrary our analysis suggests that fertilizer use can be increased considerably in irrigated areas.

The supplementary survey indicated that, even in Dokur, most farmers were unaware of the recommended levels. In other areas, ignorance was pervasive. This was revealed by the NCAER countrywide survey (NCAER 1978) as well.

In the Mahbubnagar region (and for nonirrigated local varieties in other regions) use of potash was not recommended; yet it was being used. The supplementary survey revealed that this was because of problems of availability: in most cases farmers had to accept whatever fertilizer (mixtures) was available in the market and, in several cases, they had to buy mixtures containing potash as well (Umrani 1979). This has important implications from the point of view of fertilizer-use efficiency and the working of the fertilizer distribution system.

Going back to Table 11, it is apparent that even where fertilizer use was high, the entire area under major fertilizer-using crops was not fertilized. We had commented on this earlier in the context of the overall data. Table 12 shows the extent of variation in the use of nitrogen over years as well as across farm sizes for the most important fertilizer-using crops in different regions.

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15. Risks and nonprofitability of the recommended levels could also be important reasons.

Table 12. Variation in rate of application (kg/ha fertilized) and percentage of area fertilized with nitrogenous fertilizers for selected crops, over 3 years and three farm-size classes.

Region/ Village/ crop	1975-76		1976-77		1977-78		Small		Medium		Large	
	Fert. used (kg/ha)	% of area fertil-ized	Fert. used (kg/ha)	% of area fertil-ized	Fert. used (kg/ha)	% of area fertil-ized	Fert. used (kg/ha)	% of area fertil-ized	Fert. used (kg/ha)	% of area fertil-ized	Fert. used (kg/ha)	% of area fertil-ized
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
Mahabubnagar												
Aurepalle												
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

The table shows that in both the Mahbubnagar villages, almost the entire area under HYV of paddy was covered over time. In the Akola and Sholapur regions, however, interyear and intersize variations in rates and area fertilized were considerable. The table suggests that in highly irrigated areas, future growth in fertilizer consumption would be through increases in the rate of application on irrigated crops and through spread of fertilizer use to nonirrigated crops. There was no indication that the latter would spontaneously follow because, even after more than 20 years of experience with fertilizer, farmers have not shown any willingness to extend its use to nonirrigated crops. It follows that technological strategies (varieties and agronomic management practices) that generate high response under low-rainfall (moisture) conditions should receive top priority in research for achieving real growth in the productivity of nonirrigated crops.

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

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

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

Crops	irrigeted/ nonirrigated	Rate of application (kg/ha fertilized)		
		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 reveals one interesting feature: except for paddy, the irrigated rates of application of nitrogen were not very different from the corresponding nonirrigated rates. With regard to phosphorus and potash, however, the irrigated rates were higher. It should be noted that this district has been identified as an area of relatively assured rainfall, with good scope for fertilizer use under rainfed conditions (Venkateswarlu 1979).

One other aspect—fertilizer use under sole- and mixed-cropping situations—needs to be highlighted. Mixed cropping or intercropping is an important practice in semi-arid agriculture (Jodha 1979) for several reasons. The gross cropped area devoted to mixed cropping was 37% in Sholapur, 78% in Aurepalle, and 20% in Dokur. Mixed crops accounted for only 16% of the total fertilizer used in Sholapur, and 31% in Akola. In Aurepalle, the figure was negligible and in Dokur, fertilizer was not used on mixed crops at all. Thus, it appears that fertilizer use was largely confined to sole-crop situations, 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 with protecting themselves against total crop failure (by resorting to mixed cropping) would not increase the risk of capital loss by using fertilizer.

The Akola situation has been more closely analyzed because of the relatively larger extent of intercropping and higher use of fertilizer under mixed cropping in this region. Table 14 presents data on fertilizer use under sole-cropped and mixed-cropping situations for sorghum, groundnut, and cotton—the three base crops which form a part of nearly all the intercropping schemes in the region.

The table clearly shows that for all the three crops, the rates of fertilizer application were significantly 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 when compared to the sole-crop situation. Data on the percentage of cropped area fertilized indicate that intercropping systems with groundnut and HYV of cotton as base crops, 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 under the corresponding sole-crop situation for these crops. The data also revealed that intercrops using high-response varieties (sorghum and cotton HYV) were more extensively fertilized.

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

Agronomic Management of Fertilizer

The evidence presented so far suggests that farmers are aware of the relative response of a crop to fertilizer application and decide accordingly. We now present some findings that indicate how farmers manage their fertilizer input in terms of choice of fertilizer material, timing of application, and use of different plant nutrients. These are important determinants of the technical efficiency of fertilizer use. The information would help identify aspects requiring more emphasis in extension programs.

Sources of plant nutrients. Data on fertilizer materials used by farmers revealed that in all the regions, straight fertilizers—urea mostly—were the main source of nitrogen, while fertilizer mixtures provided phosphorus and potash. In Akola, fertilizer mixtures provided a significantly higher fraction of nitrogen. Supplementary surveys indicated that sale of fertilizer mixtures (prepared in the cooperative sector) was often tied to cooperative loans. In all cases, the sole use of nitrogen fertilizer provided flexibility in fertilizer usage during the crop-growth period. Another important point revealed by the surveys was that farmers were more or less compelled to accept whatever fertilizer material was available.

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. The ratio came to 4:1 in Sholapur, 2.6:1 in Akola, 3.2:1 in Aurepalle, and 3.6:1 in Dokur. Thus, in all the regions, fertilizer use was heavily biased towards nitrogen. The situation in Sholapur and Dokur reflected a relatively greater imbalance.

Table 14. Rate of application of plant nutrients (kg/ha fertilized), and extent of area fertilized for important crops grown under sole- and mixed-cropping conditions in Akola villages (1975-78).

Crop	% of cropped area devoted to mixed cropping	Share of mixed crops in total $N+P_2O_5+K_2O$ used on the crop	Rate of application (kg/ha fertilized) for					
			Sole crop			Mixed crop		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
Sorghum								
Local	97	65	20 (26)[1]	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)

1. Figures in parentheses indicate percentage of area fertilized.
b = Less than 0.5.

Table 15 looks at this problem from the point of view of area fertilized with different nutrients. It shows that 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, where it 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 clear. In all the regions except Akola, nearly 60-65% of the fertilized area did not receive any phosphatic fertilizer. It may be noted again that the fertilizer credit policy of the cooperatives has played an important part in achieving a relatively more balanced fertilizer-use pattern in Akola.

Table 15. Distribution of fertilized area according to use of different nutrients (1975-78).

District/ village	Percentage of fertilized area receiving				Total fertilized area
	Nitrogen only	Phosphorus only	$N+P_2O_5$	$N+P_2O_5+K_2O$	
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

The soils of the regions studied are generally not deficient in potash; and with respect to phosphorus also, the response under dryland conditions has been found to be low or nonsignificant (Venkateswarlu 1979, Umrani 1979). This may be one reason for the observed imbalance. But we have seen that in Sholapur and Mahbubnagar regions, fertilizers were most used on irrigated crops. This explanation, therefore, would not hold. The SAT reflects to an extent the trend in the country as a whole. However, the adverse long-term effects of imbalance in fertilizer use are likely to emerge more strongly on relatively poorer soils that 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 fertilizer (Desai et al. 1973). What causes concern is the persistence of this tendency—even after 15-20 years of experience—in areas which consume substantial quantitites of fertilizer.[16]

Timing of fertilizer application. Table 16 shows the fertilization practice of farmers in terms of timing of nitrogen application. Use of phosphorus and potash was confined to basal application.

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

In Sholapur, Akola, and Aurepalle single application of nitrogen (as basal or a single, postsowing application) was found to be the dominant practice. In Dokur, a majority of fertilizer Users applied nitrogen more than once, as availability of irrigation provided for greater flexibility.

Postsowing application of nitrogen was considered more important in Sholapur than in other regions. This suggests that farmers were reluctant to invest in fertilizer at the time of sowing, preferring to follow a flexible pattern which offered some protection against uncertainty. That farmers preferred this strategy in spite of their using fertilizer mostly for irrigated crops, indicates the inhibiting impact of an unstable environment. This aspect has been recognized by agrobiological researchers with reference to nonirrigated crops, and the current thinking is that use of nitrogen should be flexible and related to the available soil moisture (Venkateshwarlu 1979, Vijayalakshmi 1979, and Umrani 1979).

Table 16. Timing of nitrogen application (1975-76).

District/ village	Percentage of nitrogen users resorting to						
	Basal appli-cation (BA) only	BA + one appli-cation	BA + two appli-cations	BA + three appli-cations	Postbasal application only: One appli-cation	Two appli-cations	Three appli-cations
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.

Further analysis of timing of fertilizer use. Data on monthly pattern of fextilizer consumption in different regions revealed considerable variation in the seasonal pattern of fertilizer use. We hypothesized that these variations (seasonal as well as interyear) were induced mainly by variations in the rainfall pattern. This hypothesis was tested with respect to variation in fortnightly consumption of nitrogenous fertilizer over June to November—the period of maximum rainfall. The simple model used involved regression of current and previous fortnight's rainfall on current fortnightly consumption of nitrogenous fertilizer.

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

F_t = consumption of nitrogenous fertilizer during fortnight t expressed as percentage of total nitrogen used during the year.

$RAIN_t$ = rainfall in fortnight t in mm.

$RAIN_{t-1}$ = rainfall in previous fortnight in mm.

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

Data for all the 3 years were pooled, and linear regression for each region estimated separately. These are presented in Table 17.

Table 17. 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[1]	0.0232	0.0990***	-0.0144
	(0.011)	(0.227)	(3.850)	(0.404)
$RAIN_t^2$	0.7E-5	-0.9E-4	-0.7E-3***	0.2E-4
	(0.025)	(0.220)	(3.904)	(0.192)
$RAIN_{t-1}$	0.1179*	-0.0150	-0.0067	0.0977**
	(1.761)	(0.155)	(0.244)	(2.619)
$RAIN_{t-1}^2$	-0.5E-3	-0.1E-4	0.1E-3	-0.3E-3**
	(1.569)	(0.038)	(0.663)	(2.194)
R^2	0.055	0.021	0.081	0.208

1. Figures in parentheses are t values; *, **, and *** indicate statistically significant at 10%, 5%, and 1% probability levels, respectively.

The estimated regressions explained a very small fraction of the total variation in the dependent variable, perhaps because of the omission of several other variables like cropping pattern, sowing dates, availability of irrigation, and availability of fertilizer on time. 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 in Alfisols. The farmers' decisions on the timing of fertilizer use were influenced by rainfall—the major determinant of soil moisture in the rainy season. This effect was discernible in the low-rainfall regions of Mahbubnagar. The regression coefficients with regard to Vertisols were statistically nonsignificant especially for Akola, which has a higher and more stable pattern of rainfall. Regarding the 2-week lag effect of rainfall, it was found that rainfall during the previous fortnight tended to influence fertilizer use in Dokur. In Aurepalle, where the soil is of a lighter texture and more shallow (signifying lower moisture-holding capacity), fertilizer use followed rains after a shorter time lag. In both Mahbubnagar and Sholapur regions, the quadratic terms of the rainfall variable were negative. This implied that with higher rainfall nitrogen use increases but at a decreasing rate.

It may be recalled that in the Sholapur and Nahbubnagar regions, fertilizer use was largely confined to irrigated crops. Despite this, the effects of rainfall were more clearly seen in these regions when compared with Akola, where fertilization of rainfed crops was common. Farmers in the low-rainfall Alfisol regions of the SAT thus appeared to be responsive to changes in rainfall, regardless of the availability of irrigation.

Use of Organic Manures

Use of organic manures as fertilizer is a traditional practice among farmers. Farmyard manure, cakes and other organic wastes, and sheep pennings were the materials used for manuring in the selected villages. The use of farmyard manure—the most important among these manures—was studied on the basis of data for 1975-76 and 1976-77. Table 18 indicates how use of organic manures and fertilizers was integrated and the percentage of cropped area that benefited from different manuring strategies.

Table 18. 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	12.1	6.8	4.6	0.7
Akola	41.7	16.8	19.9	5.0
Mahbubnagar				
Aurepalle	35.3	22.1	7.4	5.8
Dokur	45.3	4.8	28.6	11.9

The first column of the table shows that even in a progressive village like Dokur, more than half the cropped area did not benefit from either organic or inorganic fertilization. Nearly 42-45% of the cropped area came under some kind of manuring in Akola and Dokur, while in the Sholapur region, it was only 12%. The fertilized area in the Sholapur region was smaller, perhaps because: (1) a higher percentage of area was set aside for nitrogen-fixing pulse crops; and (2) postrainy-season cultivation was taken up after monsoon fallowing. Results at ICRISAT Center have shown that considerable nitrogen is mineralized during the fallowing period. This source is readily available to crops growing in receding soil moisture (Rego et al. 1982).

The area receiving both fertilizer and manures constituted a relatively small proportion of the total area receiving fertilizer (column 3 + column 4) in the Sholapur and Akola regions. This means that both manures and fertilizers were used as alternative fertilization strategies in these regions, and that their integrated use was not common. The proportion of fertilized area also receiving organic manures was nearly 30% in Dokur and 44% in Aurepalle.

Dokur was a special case because, in this village, fertilized area substantially exceeded manured area, 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 19, which provides data on the use of organic manures on irrigated and nonirrigated land, shows that in all the regions except Dokur, organic manure was mostly used on nonirrigated land. It may be recalled that fertilizer use was generally concentrated on irrigated land in Sholapur, Aurepalle, and Dokur. We have also shown (Table 18) that in Sholapur and Akola, farmers used fertilizer and manure as alternatives (substitutes)• Table 19 explains that this segmentation was largely because of alternative strategies adopted on irrigated and nonirrigated land. The Dokur case is important in that it showed that fertilization of nonirrigated land was totally ignored. The use of fertilizers and manures in combination on irrigated land reflected a more balanced land management but, in the process, more than 40% of the cropped land went unfertilized.

Table 19. Irrigation and use of organic manures (1975-77).

District/ village	Share of irrigated land in total manure used (%)	Rate of application/manured ha (t)	
		Irrigated	Nonirrigated
Sholapur	34	3.8	2.8
Akola	2	4.0	1.6
Mahbubnagar			
Aurepalle	39	10.9	6.8
Dokur	98	8.8	2.0

Table 19 shows that the rates of fertilizer application were significantly-higher on irrigated land in all the regions. The rates ranged from about 4 t/ha in the Sholapur and Akola regions to 9-11 t/ha in Mahbubnagar. The rates for nonirrigated land lay in the region of 2-3 t/ha except in Aurepalle, where it was nearly 7 t/ha.

It was difficult to accept that farmers would leave a sizable fraction of their cultivated land unmanured year after year. To investigate this, the manuring history of plots that were manured during any of the 3 years (1975-76 through 1977-78) was examined. The results are summarized in Table 20.

The table shows that, generally, plots were not manured every year. In most cases, manuring was done once in 3 years or more. This implied that in any given year, a maximum of one-third of the cropped area would be manured. But data, presented in Table 18, showed lower values, indicating an even greater time lag between manurings. Data covering more than 3 years would be necessary to arrive at the exact picture. However, the frequency of use of organic manure reflects the approach of farmers faced with inadequate supplies of manure.

Table 20. Frequency of use of organic manures.

District/village	Proportion of plots manured Once in 3 years or more	 Twice in 3 years	 All 3 years
Sholapur	78	15	7
Akola	69	27	4
Mahbubnagar			
Aurepalle	62	26	12
Dokur	52	26	22

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

Information on the use of organic manures was also collected through supplementary surveys. The responses indicated that all the farmers used organic manure and nearly every one of them 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 t/ha in the Sholapur and Akola regions, and 6-8 t/ha in the Mahbubnagar area. For irrigated land, the corresponding values were 6-8 t/ha in the Sholapur and Akola regions, and 9-12 t/ha in the Mahbubnagar area.

These findings indicate that farmers were aware of the value of manuring, but because of inadequate supplies had to reduce the rates of application as well as area fertilized and even forgo manuring of poorer soils. In spite of this, a conscious attempt was made to manure the more intensively cultivated lands at higher rates and at greater frequency.

Conclusions

The main focus of this chapter was on understanding the fertilization practices of farmers in different agroclimatic regions of SAT India. The important conclusions of the study are listed below:

1. The results convincingly demonstrated that farmers took into account the relative profitability of fertilizer application while making their fertilizer-allocation decisions. This obviously favored the irrigated crops, the high-value commercial crops, and the highly fertilizer-responsive and high-yielding varieties of cereal crops. When capital was scarce, these crops claimed all the fertilizer, and the low-response, traditional varieties of crops, grown over a large area, went unfertilized.

2. In the low-rainfall areas, fertilizer use was confined to irrigated crops: soil-moisture conditions on nonirrigated land were too unreliable to permit fertilizer use. However, in areas with relatively higher and more stable

rainfall and high moisture-retentive soils, nonirrigated crops were also fertilized to a significant extent, but usually at low rates of fertilizer application.

3. Even in the relatively high fertilizer-using areas (irrigated areas and those receiving high rainfall), there was still potential for increasing fertilizer use. The slack was particularly noticeable in the fertilized areas. Such areas could continue to support high demand for fertilizer in the future.

4. The contrast between Sholapur (or even Aurepalle) and Dokur can be used to extrapolate the likely impact of development of irrigation in the low-rainfall SAT. This intensification has cropping-pattern implications which are well known (Jodha 1979). In terms of fertilizer use, our analysis suggests that this would also lead to concentration of fertilizer (and manure) use on irrigated crops. This is inevitable so long as capital constraints remain. The only force which can alter this course of development is rapid advancement in the production technology of dry crops.

5. There were a number of indications supporting the rationality of the farmer's behaviour: his decisions regarding crops to be fertilized, rates of fertilizer application, and adjustments to seasonal conditions reflected this phenomenon.

Finally, the enormous diversity of agroclimatic conditions in the Indian SAT is evident even from the study of the three regions presented in this chapter. This makes any generalization hazardous. What comes out clearly is the need to undertake a more detailed classification of the SAT environment and to design technological strategies suited to specific situations.

III. Fertilizer Use on High-Yielding Varieties of Sorghum and Pearl Millet[17]

Sorghum and pearl millet are the two most important cereals grown on drylands in SAT India. These two have traditionally formed part of a highly unstable, low-cost, and low-output farming system, and are considered in the market as relatively inferior food grains (Jodha 1973). Unremunerative response (Kanwar et al. 1973) and high level of weather-induced instability in yield (Bapna et al. 1979) have been hypothesized as the two main factors responsible for poor performance of these millets so far as use of modern inputs like fertilizer is concerned.

This traditional pattern appears to be changing in the wake of the introduction of high-yielding varieties and, despite the rather modest performance of the HYV of sorghum and millets, farmers have apparently started using fertilizer on these crops also (NCAER 1974, 1978). This trend needs careful monitoring not only in view of its impact on the yield of these crops but also because this may mark the beginning of intensive fertilizer use under dryland conditions—a phenomenon crucial to future growth in productivity and fertilizer demand in India (Desai 1978).

This chapter provides information on levels of fertilizer use on HYV of sorghum and pearl millet and the pattern of fertilizer adoption and diffusion in different areas. The main objectives are: (a) to determine the extent and level of fertilizer use on HYV of sorghum and pearl millet in different areas, and (b) to examine the trend in fertilizer use and its diffusion over time.

Data Source and Methodology

The data for this analysis comes from "Sample Surveys for Assessment of High-Yielding Varieties Programme." The surveys were carried out by the Indian Agricultural Statistics Research Institute (IASRI), New Delhi, from 1969-70 to 1973-74, and covered 88 districts spread over 15 states.

Two types of enquiries were conducted under the project: Agronomic and Agroeconomic Enquiry, and Yield Estimation Surveys. The Agronomic and Agroeconomic Enquiry was based on a sample of 320 cultivator households in each district and elicited information on the area under the HYV of the crop concerned and the extent of adoption of improved practices. The Yield Estimation Surveys measured the yield levels of HYV and local varieties in each district with crop-cuts on 80 fields for each of the varietal types.

Data on fertilizer use on sorghum, pearl millet, and other crops (rice or wheat) in the selected districts were taken from the project's annual report for 1973-74 (Raheja et al. 1976).[18] Sorghum crop was studied in 20 districts during the rainy season, and in one district during the postrainy season. Pearl millet was studied in 21 districts during the rainy season, and in 5 districts during the postrainy season. Almost all these districts fall in the Indian SAT.

To analyze the trend in fertilizer use over time, data for only those 8 districts (4 each for sorghum and pearl millet) that were covered continuously for 6-7 years up to 1976-77 were used.

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17. This section is a condensed version of Jha et al. 1981.
18. The coverage was substantially reduced from 1974-75 onwards which also happened to be the year when fertilizer prices rose sharply. These considerations prompted the selection of this particular year for our study.

Description of selected districts and spread of HYV of sorghum and pearl millet. The survey on high-yielding varieties of sorghum covered more than 3900 cultivator households spread over 21 districts in 4 states. As can be seen from Appendix III, the concentration of cultivator households growing sorghum was high in Maharashtra and Karnataka—the major sorghum-producing states. In almost all the districts selected (with the exception of Nanded, Wardha, and Shimoga), sorghum was an important crop. The sample for pearl millet was more diffused, covering about 4700 cultivators in 26 districts over 8 states. It may be noted that pearl millet was not a very important crop in 13 of the 26 selected districts of Andhra Pradesh/ Tamil Nadu (except Tirunelveli), and some districts of Maharashtra. This has to be borne in mind while interpreting the results.

Appendix III also shows that the selected districts covered a wide range of soil and rainfall conditions. Most sorghum-growing districts had black or red soils and, with the exception of Shimoga, had less than 1200 mm annual (normal) rainfall. Interdistrict variation in rainfall and soil type was higher in the pearl millet producing districts. The normal rainfall ranged from 219 mm/yr in Rohtak to 1211 mm/yr in Chingleput. Almost all the major soil types were represented.

The pearl millet hybrids had higher coverage compared to sorghum HYV (Appendix III). In 8 districts, more than 60% of the cropped area was covered by hybrids (against 3 for sorghum), and in only 5 districts (against 10 for sorghum), was the spread less than 20%. Even if the 13 districts where the crop was unimportant were excluded, this superiority held.

It was further observed that in nearly half the districts studied, sorghum HYV were grown primarily under nonirrigated (less than 20% area irrigated) conditions; on the other hand, in 16 out of 26 districts, more than 60% of the area under pearl millet hybrids was irrigated. Interestingly, in 12 (out of 13) nontraditional districts, spread over the southern states, the pearl millet hybrids were grown predominantly under irrigated conditions. The remaining 13 traditional pearl millet producing districts (in Gujarat, Haryana, Rajasthan, Madhya Pradesh, and Maharashtra) presented an interesting contrast: in 4 districts, more than 60% of the hybrid area was irrigated, in 5 the hybrids were grown primarily under rainfed conditions. The districts under both categories were spread over a wide range of soil and climatic conditions.

In general, adoption of sorghum hybrids was lower but more extensive under rainfed conditions. The performance of the pearl millet hybrids depended more heavily on the availability of irrigation (Bapna and Murty 1976).

Adoption of Fertilizer for Sorghum and Pearl Millet

Observed patterns of fertilizer use on a particular crop arise from three related decisions: (1) whether to use fertilizer or not; (2) what should be the rate of application; and (3) how much area to cover. These decisions are influenced by a host of technological, socioeconomic, and psychological variables. These influences are examined in Chapter IV. Here, the observed estimates of these parameters are presented to provide an idea regarding the status of fertilizer use on HYV of sorghum and pearl millet.

Adoption of fertilizer. Table 21 shows the level of adoption of fertilizer for HYV of sorghum and pearl millet in different districts.[19] Considerable

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[19] These were obtained from the distribution of irrigated and nonirrigated plots for each district in the Yield Estimation Survey. Because the data sources are different, one observes some inconsistencies when comparing fertilizer use under nonirrigated conditions (Table 1) and percentage of HYV area under irrigation (Appendix III). The differences are, however, minor.

interdistrict variation in the percentage of farmers using fertilizer was noted. In general, adoption levels appeared to be fairly high: in 7 (out of 21) districts under sorghum, and 9 (out of 22) districts under pearl millet, more than 80% of the farmers growing HYV used fertilizer.

Table 21. Adoption of fertilizer for HYV of sorghum and pearl millet in selected districts (1973-74).

Sorghum districts			Pearl millet districts		
District (State)	% of HYV growers using fertilizer	% of users fertilizing non-irrigated HYV crop	District (State)	% of HYV growers using fertilizer	% of users fertilizing non-irrigated HYV crop
Jalgaon (Man)	97	98	Hissar[3] (Har)	69	5
Ahmadnagar (Nah)	72	45	Rohtak[3] (Har)	43	44
Sangli (Man)	72	81	Jaipur[3] (Raj)	50	75
Aurangabad (Mah)	24	88	Jalgaon[1] (Mah)	90	100
Parbhani (Mah)	70	96	Ahmadnagar[3] (Mah)	17	72
Bhir (Mah)	14	100	Sangli (Mah)	18	0
Satara (Mah)	81	85	Aurangabad[3] (Mah)	21	100
Osmanabad (Mah)	28	100	Parbhani (Mah)	74	100
Buldhana (Mah)	74	98	Bhir[3] (Mah)	12	88
Akola (Mah)	73	98	Sholapur (Mah)	47	40
Amravati (Mah)	80	100	Morena[3] (MP)	94	100
Nanded (Mah)	35	100	Guntur (AP)	41	2
Wardha (Mah)	83	100	Chittor (AP)	84	1
Nagpur (Mah)	94	100	Nellore (AP)	93	0
Mandsaur (MP)	47	100	Coimbatore (TN)	88	1
Belgaum (Kar)	88	77	Madurai (TN)	46	30
Bellary (Kar)	78	90	Tirunelveli[3] (TN)	94	0
Shimoga (Kar)	96	96	Chingleput (TN)	81	7
Mysore (Kar)	54	76	Coimbatore[1] (TN)	81	2
Anantapur (AP)	76	12	Madurai[1] (TN)	50	0
Shimoga[1] (Kar)	100	1	Chingleput[1] (TN)	50	6
Gujarat[2]	NA	NA	Bellary[1] (Kar)	100	2

Source: Yield Estimation Survey data, Raheja et al. 1976.

1. Postrainy-season crop.
2. This information was not available for Banaskanta, Kaira, and Rajkot districts in Gujarat, and for Tirunelveli (postrainy) in Tamil Nadu.
3. Traditionally important pearl millet producing districts.

NA = not available.

Data on the proportion of fertilizer users who had taken to fertilization of the nonirrigated (HYV) crop are interesting. The table shows that fertilizer use under nonirrigated conditions was a common and extensive practice, particularly for HYV of sorghum. In 16 out of 21 districts, more than 80% of the fertilizer adopters used fertilizer for the nonirrigated HYV crop of sorghum. For pearl millet hybrids, this was true only of 5 out of 22 districts;

in as many as 12 districts, less than 10% of the fertilizer users resorted to this practice. A majority of these were unimportant pearl millet producing districts where, as shown earlier, the HYV were almost invariably grown under irrigated conditions. In the major pearl millet producing districts, fertilizer use on the nonirrigated crops was common.

Levels of fertilizer use. Table 22 shows the average level of fertilizer use—measured as the rate of plant nutrients used per hectare of cropped area—for high-yielding and traditional varieties of the two crops in different districts. Appendix IV provides information on rates of application of individual plant nutrients per fertilized hectare, and the extent of cropped area fertilized with these nutrients.

Table 22. Average level of fertilizer ($N+P_2O_5+K_2O$) application on high-yielding and traditional varieties of sorghum and pearl millet in selected districts.

Sorghum districts			Pearl millet districts		
	Average rate (kg/ha)			Average rate (kg/ha)	
District (State)	HYV	Local	District (State)	HYV	Local
Jalgaon (Mah)	50	19	Banaskanta[2] (Guj)	11	2
Ahmadnagar (Mah)	45	0	Kaira[2] (Guj)	32	16
Sangli (Mah)	30	0	Rajkot[2] (Guj)	39	16
Aurangabad (Mah)	18	0	Hissar[2] (Har)	32	5
Parbhani (Mah)	29	0	Rohtak[2] (Har)	39	17
Bhir (Mah)	18	0	Jaipur[2] (Raj)	28	4
Satara (Mah)	48	0	Jalgaon[2] (Mah)	37	14
Osmanabad (Mah)	23	2	Ahmadnagar[2] (Mah)	66	5
Budhana (Mah)	68	9	Sangli (Mah)	28	1
Akola (Mah)	40	0	Aurangabad[2] (Mah)	19	2
Amravati (Mah)	71	5	Parbhani (Mah)	12	0
Nanded (Mah)	19	0	Bhir[2] (Mah)	12	0
Wardha (Mah)	39	1	Sholapur (Mah)	8	0
Nagpur (Mah)	59	2	Morena[2] (MP)	81	11
Mandsaur (MP)	84	22	Guntur (AP)	55	1
Belgaum (Kar)	117	19	Chittoor (AP)	107	0
Bellary (Kar)	28	8	Nellore (AP)	59	0
Shimoga (Kar)	75	21	Coimbatore (TN)	141	5
Mysore (Kar)	27	0	Madurai (TN)	46	2
Anantapur (AP)	11	0	Tirunelveli[2] (TN)	82	8
Shimoga[1] (Kar)	113	0	Chingleput[2] (TN)	82	0
			Coimbatore[1] (TN)	79	20
			Madurai[1] (TN)	19	1
			Tirunelveli[1,2] (TN)	10	1
			Chingleput[1] (TN)	71	0
			Bellary[1] (Kar)	108	0

Source: Raheja et al. 1976.

1. Postrainy-season crop.
2. Traditionally important pearl millet producing districts.

The level of total plant nutrients ($N+P_2O_5+K_2O$) used per hectare of cropped area indicates the average intensity of fertilizer use. Table 22 shows how widely this varies from district to district. The average level was found to be less than 20 kg/ha of cropped area in 4 districts growing HYV of sorghum and 7 districts under pearl millet; in 6 districts under sorghum and 9 growing pearl millet, the levels exceeded 60 kg/ha. In general, districts with higher adoption of fertilizer for sorghum (Table 21) also showed higher average level of fertilizer use (r = +0.563) as did districts with higher rainfall (r = +0.490). The correlations of average rates with percentage area under HYV with or without irrigation were positive but not statistically significant. For pearl millet hybrids, the average rate of application was significantly associated with adoption (r = +0.605), and extent of HYV area irrigated (r = +0.448). With regard to the other variables—coverage under HYV and rainfall—the correlations were not significant. The findings suggest the importance of rainfall (for sorghum) and irrigation (for pearl millet) as determinants of fertilizer use on these crops.

Table 22 also shows that the local varieties of these crops were, generally, either not fertilized or fertilized at very low rates. In 15 districts growing sorghum and 19 pearl millet, the average rate was either zero or nominal (less than 5 kg/ha).

Correlations were worked out between actual rates of application, extent of area fertilized (Appendix V), and some other variables. These indicate that:

1. The actual rates of fertilizer application (both N and P_20_5) for sorghum were not associated with the spread of HYV, irrigated area under HYV, adoption of fertilizer, or rainfall. For pearl millet, irrigated area under HYV was positively associated with N rates, and adoption with P_2O_5 rates.

2. The percentage of area under sorghum fertilized with N and P_2O_5 was significantly correlated with adoption and rainfall. For pearl millet, spread of HYV, irrigated area under HYV (with N), adoption of fertilizer, and rainfall (with P_2O_5) were positively correlated with the area-fertilized variables.

3. The nitrogen and phosphorus rates were not correlated for sorghum, but the areas fertilized with these nutrients were positively correlated. For pearl millet, both rates and areas fertilized with nitrogen and phosphorus were correlated, and the rate and area fertilized with the same nutrient was also positively correlated.

These correlations indicate that higher spread of HYV did not imply higher rates of fertilizer application. There was some indication that the fertilized area was higher in districts with a larger area under HYV. Secondly, higher level of fertilizer adoption was more strongly associated with extent of area fertilized. Thirdly, rainfall was significantly associated with the extent of area fertilized. All these pointed toward area fertilized being more variable than rate of application. Finally, the significant association between areas fertilized with nitrogen and phosphorus suggested efforts toward more balanced use of fertilizer. This was more strongly indicated in the case of pearl millet for which both rates of application and area fertilized with N and P_2O_5 tended to move together.

Pursuing the results further, district estimates presented in Appendix III did not reveal any trend in broad soil types. As for varietal differences in fertilizer use, districts growing pearl millet hybrids showed some interesting results.[20] HB 1 was the dominant hybrid in 5 districts, HB 3 in 15, and HB 4 in

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[20] CSH 1 was the dominant sorghum hybrid in 19 of the 21 districts studied (Appendix III). Therefore, interregional differences in cultivar adoption were not analyzed.

6 (Appendix III). In general, the districts where HB 4 was the dominant hybrid showed higher fertilizer-use values (in terms of rates as well as percentage of area fertilized) compared with districts in which HB 1 was the most widely grown variety. Interestingly, this ranking agreed with experimental evidence on the response of pearl millet hybrids to fertilizer application (Bapna and Murty 1976). This lends support to the hypothesis that farmers are aware of the relative responses of different varieties and that this awareness affects their fertilizer-use decisions.

Fertilizer use under irrigated and rainfed conditions. Appendix III shows that, in several districts the HYV were grown under irrigated conditions. From the point of view of SAT agriculture in general, there is greater interest in monitoring the situation for the primarily nonirrigated crop which is quantitatively so important. Tables 23 and 24 give estimates of actual rates of application and percentage of area fertilized with each nutrient under irrigated and nonirrigated conditions.

Considering sorghum first, (Table 25), the modal classes for N, P_2O_5, and K_2O application were found to be 41-60 kg, 31-40 kg, and 11-20 kg per fertilized ha, respectively under irrigated conditions. Under nonirrigated conditions, these were 21-40 kg/ha, 21-30 kg/ha, and 11-20 kg/ha, respectively. The differences between irrigated and nonirrigated distributions were not as sharp with reference to N rates, and more than half the number of districts fell in the supramodal classes. The areas fertilized with N, P_2O_5, and K_2O were clearly lower under nonirrigated conditions, although with respect to this parameter also the distinction was not so sharply defined for nitrogenous fertilizers; the percentage of area fertilized with nitrogen exceeded 80% in a significant number of districts even under nonirrigated conditions.

For pearl millet (Table 25) the modal classes for N, P_2O_5, and K_2O application were 41-60 kg, 21-30 kg, and less than 10 kg per fertilized ha under irrigated conditions; and 21-40 kg, less than 20 kg, and less than 10 kg per fertilized ha respectively under rainfed conditions. It was also noted that a significant number of districts belonged to the supramodal classes for N and P_2O_5 application rates. With respect to area fertilized, the nonirrigated distributions clearly indicated relatively lower values.

The conclusions, summarized in Table 25, clearly indicate higher fertilizer-use parameters for nonirrigated sorghum when compared to pearl millet. Under irrigated conditions, although the modal values for the two crops—presented in Table 25—were similar, the overall distribution indicated a somewhat higher level of nitrogen use for pearl millet hybrids. Comparison of fertilized areas under irrigated and nonirrigated conditions revealed that the areas fertilized with P_2O_5 and K_2O recorded sharper declines when compared to areas fertilized with N. This follows from the fact that there is an element of flexibility where nitrogen application is concerned (it could be applied during postsowing stages also),while in the case of P_2O_5 and K_2O application it is not so.

The modal rates presented in Table 25 compared favorably with those reported for different states for 1975-76 (NCAER 1978). The 1969-71 estimates for sorghum (all-India) also compared with the modal classes obtained in an earlier study (NCAER 1974). While this improves our confidence in these estimates, the comparison also suggests that rates of fertilizer application on these crops did not record any significant gains over 1969-70 to 1975-76. We shall come back to this later.

Stratification of these data according to major soil types revealed that, generally, the rates of fertilizer application for nonirrigated sorghum were higher on black soils than on red and lateritic soil groups: medium black soils

Table 23. Fertilizer use on HYV of sorghum under irrigated and nonirrigated conditions in different districts (1973-74).

District (State)	Rate of application (kg/ha fertilized)						% of area fertilized with different nutrients					
	Irrigated crop			Nonirrigated crop			Irrigated crop			Nonirrigated crop		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Jalgaon (Mah)	25	16	0	50	30	13	86	72	0	74	56	22
Ahmadnagar (Mah)	77	33	b	64	22	0	67	47	b	42	13	0
Sangli (Mah)	65	24	15	63	27	12	69	34	32	16	8	2
Aurangabad (Mah)	b	b	b	56	30	15	b	b	b	25	15	7
Parbhani (Mah)	na	na	na	47	19	18	na	na	na	43	25	25
Bhir (Mah)	0	0	0	24	20	22	0	0	0	25	44	25
Satara (Mah)	56	26	15	61	27	12	100	37	37	57	24	19
Osmanabad (Mah)	40	18	14	26	21	16	43	34	34	37	31	31
Buldhana (Mah)	40	40	b	33	33	18	100	100	b	88	88	57
Akola (Mah)	na	na	na	48	27	17	na	na	na	52	42	21
Amravati (Mah)	42	31	21	42	27	23	97	79	74	84	66	44
Nanded (Mah)	0	0	0	30	15	4	0	0	0	50	30	15
Wardha (Mah)	35	17	15	45	18	15	58	58	48	60	43	33
Nagpur (Mah)	na	na	na	35	27	16	na	na	na	83	81	60
Mandsaur (MP)	na	na	na	63	24	29	na	na	na	81	71	54
Belgaum (Kar)	100	35	29	89	18	17	100	81	77	86	36	30
Bellary (Kar)	20	14	14	12	11	11	85	82	82	69	70	68
Shimoga (Kar)	44	25	25	38	25	23	78	75	65	92	92	88
Shimoga[1] (Kar)	57	35	33	na	na	na	97	95	74	na	na	na
Mysore (Kar)	60	38	32	36	30	31	91	86	80	19	4	5
Anantapur (AP)	50	b	0	b	0	0	41	b	0	b	0	0

Source : Unpublished tabulated results of IASRI assessment survey, 1973-74.

1. Postrainy-season crop.

b = Estimate not reported because it was based on very few observations.

na = not applicable.

Table 24. Fertilizer use on HYV of pearl millet under irrigated and nonirrigated conditions in different districts (1973-74).

District (State)	Rate of application (kg/ha fertilized)						% of area fertilized with different nutrients					
	Irrigated crop			Nonirrigated crop			Irrigated crop			Nonirrigated crop		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Banaskanta[1] (Guj)	na	na	na	49	0	0	na	na	na	23	0	0
Kaira[1] (Guj)	37	45	0	35	38	0	69	19	0	80	8	0
Rajkot[1] (Guj)	38	42	0	22	23	0	87	53	0	73	50	0
Hissar[1] (Har)	46	61	b	b	0	0	67	3	b	b	0	0
Rohtak[1] (Har)	47	0	0	23	0	0	92	0	0	21	0	0
Jaipur[1] (Raj)	37	0	0	34	16	0	72	0	0	70	60	0
Aurangabad[1] (Mah)	b	b	b	30	19	18	b	b	b	35	28	16
Parbhani (Mah)	na	na	na	27	12	12	na	na	na	29	16	16
Bhir[1] (Mah)	b	b	b	25	17	16	b	b	b	20	18	18
Jalgaon[1] (Mah)	b	b	b	32	21	8	b	b	b	77	56	21
Ahmadnagar[1] (Mah)	67	40	17	57	27	49	93	35	10	66	15	4
Sangli (Mah)	60	b	b	na	na	na	47	b	b	na	na	na
Sholapur (Mah)	28	b	b	b	0	0	31	b	b	b	0	0
Morena[1] (MP)	71	25	0	48	38	0	100	100	0	91	76	0
Guntur (AP)	65	28	16	b	0	0	64	64	45	b	0	0
Chittoor (AP)	76	34	32	na	na	na	99	54	46	na	na	na
Nellore (AP)	41	22	18	na	na	na	91	67	41	na	na	na
Coimbatore (TN)	99	42	33	na	na	na	91	74	66	na	na	na
Coimbatore[2] (TN)	49	26	21	na	na	na	94	67	67	na	na	na
Madurai (TN)	35	19	19	b	b	b	81	62	62	b	b	b
Madurai[2] (TN)	18	6	6	0	0	0	91	50	50	0	0	0
Tirunelveli[1] (TN)	77	30	30	20	13	13	87	38	38	48	48	48
Tirunelveli[1,2] (TN)	32	0	0	28	b	b	13	0	0	54	b	b
Chingleput (TN)	44	31	27	na	na	na	94	77	74	na	na	na
Chingleput[2] (TN)	49	26	21	b	b	b	94	67	67	b	b	b
Bellary[2] (Kar)	64	30	26	na	na	na	98	83	79	na	na	na

Source : Unpublished tabulated results of IASRI assessment survey, 1973-74.

1. Traditionally important pearl millet producing districts.
2. Postrainy-season crop.

b = Estimate not reported because it was based on very few observations.
na = not applicable.

fared better than shallow black soils. For pearl millet, the nonirrigated rates were higher on alluvial, gray-brown, and black soils when compared to mixed red and black, red and red, and lateritic soils. These trends are in line with the moisture-holding capacities of different soils.

Table 25. Modal classes for rate of fertilizer application and percentage of area fertilized: HYV of sorghum and pearl millet (1973-74).

		Modal classes for rate of application (kg/ha fertilized)		Modal classes for % of HYV area fertilized	
Crop	Fertilizer	Irrigated	Nonirrigated	Irrigated	Nonirrigated
Sorghum	N	41 - 60	21 - 40	> 80	> 60
	P_2O_5	31 - 40	21 - 30	> 80	< 40
	K_2O	11 - 20	11 - 20	61-80	< 40
Pearl millet	N	41 - 60	21 - 40	> 80	61 - 80
	P_2O_5	21 - 30	< 20	61-80	< 10
	K_2O	< 10	< 10	41-80	< 10

Summing up, the analysis of adoption levels and application rates revealed that: (a) a substantial proportion of farmers growing HYV of sorghum and pearl millet used fertilizers on these crops. More important, they used fertilizers for the rainfed crops as well; (b) there was evidence to show that in some districts at least, local varieties of these crops were also fertilized; (c) high spread of the HYV did not always lead to higher rates of fertilizer application, but spread of HYV and extent of cropped area fertilized were positively correlated. This implies that decisions on use of fertilizers and superior varieties were related, but decisions regarding rates of application were probably taken with other considerations in view; (d) the status of soil moisture appeared to be important in fertilizer-use decisions. Accordingly, both rainfall and irrigation appeared to influence fertilizer use; (e) there was some evidence to suggest that farmers considered the relative responses of different varieties in making their fertilizer-use decisions; (f) the rate of application as well as the area fertilized with different nutrients was lower under nonirrigated conditions for both these crops. The modal rates of application for nitrogen were 40-60 kg per fertilized ha under irrigated, and 21-40 kg per fertilized ha under nonirrigated conditions. The nonirrigated rates were somewhat higher for sorghum, and the irrigated rates were higher for pearl millet. Application of phosphorus and potash was more widespread for sorghum. Under nonirrigated conditions, however, the extent of area fertilized with these nutrients was substantially lower, particularly in districts growing pearl millet; and (g) wide interdistrict variation was noticed in the fertilizer-use parameters for both these crops, underscoring the need for detailed study of the determinants of this variation and the adaptability and response behavior of different HYV.

Trend in fertilizer use. To understand the pattern of diffusion of fertilizer use and the firmness of the estimates presented in the earlier sections, the trend in fertilizer use over time was studied. Data on fertilizer-use parameters for a continuous period of 6-7 years were available for only 8 districts. Sorghum crop was covered in Mandsaur, Akola, Shimoga (both rainy and postrainy seasons); and pearl millet in Jaipur, Kaira, Hissar, and Aurangabad districts. Figure 4 shows the changes, over time, in rates of application per fertilized hectare and percentage of areas fertilized with nitrogenous fertilizer in these districts with reference to pearl millet, sorghum, and irrigated rice (or wheat).[21] The following important tendencies are revealed:

1. In general, Figure 4 indicates no systematic trend either in the rates of fertilization or in the percentage of areas fertilized for HYV of sorghum and pearl millet. The HYV of other irrigated cereals, rice and wheat, in the traditional areas of production—Shimoga, Mandsaur, and Hissar—showed greater stability, particularly with regard to area fertilized. Looking at the position in Shimoga, where HYV of sorghum are grown either as irrigated crop (postrainy season) or under conditions of high and stable rainfall (rainy season), the stabilizing influence of adequate moisture availability was clearly brought out: the rates were higher and the percentage of area fertilized was high and stable when compared with the other two sorghum-growing districts. But for pearl millet, this explanation did not seem to hold. Hissar, a predominantly irrigated district growing HYV, did not reveal a high or stable pattern (Figure 4). The number of districts are too few to draw conclusions, but the Hissar case does suggest the need to look for other variables like seasonal conditions and pest and disease incidence for a fuller understanding of temporal variation in the fertilizer-use parameters.

   In other districts, fertilizer use for both the categories of crops—millets and superior cereals—was fluctuating, although a stable (area fertilized in Kaira) or rising (rate in Akola and Jaipur) trend was observed for wheat in some districts. The spread of fertilizer use to crops like sorghum and millets or even irrigated crops in areas where the irrigation source and the environment were unstable,[22] did not seem to follow the classical sigmoid route. It should be noted that in more than 10 years (beginning 1965-66), the coverage under fertilizer has not reached 100% for sorghum and pearl millet in most of the nonirrigated districts producing these crops. It was observed (data not presented here) that there was considerable year-to-year variation in the proportion of fertilizer users also. These factors made fertilizer-use parameters unstable. It is hypothesized that this instability was primarily caused by variation in seasonal conditions conducive to fertilizer use. This hypothesis is further examined later in this section.

2. Figure 4 also shows that the percentage of area fertilized varied relatively less over time in districts where it had already attained high levels (as in Shimoga for rainy and postrainy-season sorghum; and in Kaira for pearl millet). These seem to represent areas where fertilizer has been accepted as an essential component of the production technology for HYV. Several factors—availability of adequate soil moisture, better adaptability,

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[21] These data were not available separately for irrigated and nonirrigated crops. Figure 4 is thus based on average values. One needs to note, however, that in Mandsaur and Akola (sorghum) and Aurangabad (pearl millet), the HYV were grown primarily as rainfed crop. In Shimoga (postrainy-season sorghum) and Hissar (pearl millet), on the other hand, irrigated HYV was dominant. This does provide some scope for analyzing irrigated and rainfed crops.

[22] It may be noted that in Akola, Aurangabad, and Kaira wheat cultivation has only recently assumed importance.

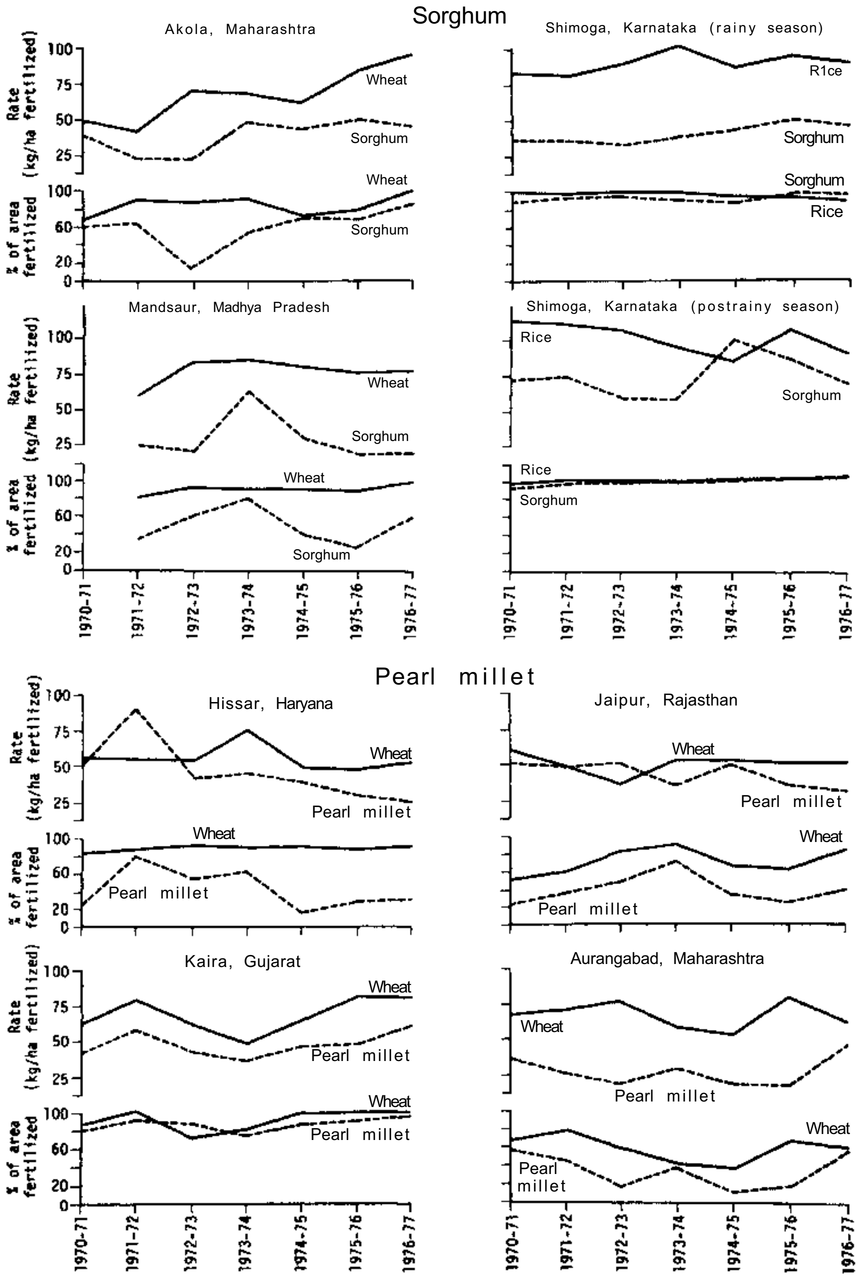

Figure 4. Trend in use of nitrogenous fertilizers for HYV of sorghum, pearl millet, and wheat/rice in indicated districts (1970-71 to 1976-77).

superior response, and lower disease/pest incidence—could be responsible for this. Other districts with lower coverage (Mandsaur, Akola, Aurangabad, Hissar, and Jaipur), represented relatively uncertain response situations in the sense that both area fertilized and rates of fertilization fluctuated, often in the same direction,

3. The tendency for the area fertilized to become stable as it reached a high level (as in most districts for irrigated rice/wheat HYV, and sorghum in Shimoga; and for pearl millet in Kaira), suggested the hypothesis that during initial stages of adoption, the parameters of the area fertilized need to be examined. Later, with adoption becoming widespread, fluctuations in fertilizer use become rate-dominated,

4. Although Figure 4 shows significant interyear variations, data for 1973-74 presented in the earlier section were typical. Most of the rate values shown in the figure ranged between 35 and 50 kg/ha, irrigated postrainy-season sorghum in Shimoga being an exception. Since 1973-74, the rate has fallen significantly only in Mandsaur; in other districts, they have remained more or less in the same modal class. The area fertilized has, however, shown a significant decline in several districts. Thus, while the modal rate estimates presented in Table 25 appear to be fairly firm, the same cannot be said of the area-fertilized parameter.

5. The position in 1974-75 was of special interest because fertilizer prices had increased sharply that year. Figure 4 shows that the rate of fertilizer application for sorghum and pearl millet went down in 4 districts (Mandsaur, Akola, Aurangabad, and Hissar) and in 5 (Mandsaur, Aurangabad, Hissar, Jaipur and Shimoga during the rainy season), the area fertilized declined compared to the situation in 1973-74. It follows that both the parameters should be examined to arrive at a correct picture about the farmers' response to price changes. Nevertheless, Shimoga (for both rainy- and postrainy-season sorghum), Akola (sorghum), and Kaira (pearl millet) stood out as exceptional districts, recording increases in average level of nitrogen used per ha in 1974-75. Further analysis revealed (data not presented here) that in these districts, there was a substantial decline in area under high-yielding varieties, implying reductions in total quantity of fertilizer used. Thus, adjustment to price and other changes seemed to have several dimensions.

Some regression results. It has been suggested earlier that seasonal conditions (rainfall, occurrence of pests/diseases, etc) could play a role in farmers' fertilizer-use decisions for nonirrigated crops. An attempt was made to study the relationship between fertilizer use on HYV of sorghum and pearl millet, and seasonal (June to August) rainfall on the basis of 4 years' data (1970-71 to 1973-74) for 17 districts growing rainy-season sorghum, and 10 districts growing rainy-season pearl millet.[23] The annual data for different years also provided information on borrowings for agricultural purposes, and we have included this variable as an indicator of credit availability in the regression model. This model thus hypothesized that seasonal conditions and capital were the main determinants of fertilizer use on these crops.24

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[23] The choice of these districts was exclusively determined by coverage in all the 4 years. The sorghum districts were Belgaum, Bellary, Mysore, Shimoga, Jalgaon, Satara, Sangli, Aurangabad, Parbhani, Bir, Nanded, Osmanabad, Buldhana, Akola, Amravati, Wardha, and Nagpur. The pearl millet districts were Guntur, Nellore, Chittoor, Jalgaon, Aurangabad, Bhir, Hissar, Rohtak, Chingleput, and Coimbatore.

[24] Lagged output price was also tried initially and the results turned out to be nonsignificant; this variable was dropped subsequently.

Six variables were used to indicate the level of fertilizer use: (a) percentage of farmers using fertilizer (ADOPTION); (b) average rate of application of $N+P_2O_5+K_2O$ in kg/ha of cropped area (AVNPK); (c) rate of application of nitrogen in kg per fertilized ha (NRATE); (d) rate of application of phosphorus in kg per fertilized ha (PRATE); (e) percentage of cropped area fertilized with nitrogen (NAREA); and (f) percentage of cropped area fertilized with phosphorus (PAREA). The 2 independent variables regressed against each of these 6 dependent variables were: rainfall (in mm) during the growth period (June to August) (JUNAUGRF). For the adoption decision, rainfall during sowing and presowing period is relevant and, therefore, we only considered rainfall (in mm) during June-July in this equation. The other variable used (CREDIT) was average borrowings (in rupees) per cultivator for agricultural purposes during the season.

Table 26. Effect of rainfall (during growing period) and credit on fertilizer use for HYV of sorghum and pearl millet.[1]

No. of districts	No. of years	Dependent variable	Regression coefficients		
			Intercept	JUNAUGRF	CREDIT
			Rainy-season sorghum		
17	4	ADOPTION	26.140	0.033** (2.180)	0.034*** (4.403)
		AVNPK	29.368	0.023** (2.122)	0.021** (2.230)
		NRATE	39.967	0.003 (0.362)	-0.005 (0.771)
		PRATE	25.109	-0.003 (0.641)	0.016*** (3.612)
		NAREA	42.334	0.028** (2.450)	0.025** (2.523)
		PAREA	33.383	0.023** (2.063)	0.017* (1.746)
			Rainy-season pearl millet		
10	4	ADOPTION	48.030	0.045* (1.898)	0.033*** (3.729)
		AVNPK	45.816	0.025 (0.940)	-0.005 (0.264)
		NRATE	55.295	-0.014 (0.677)	-0.007 (0.513)
		PRATE	31.393	-0.017 (0.878)	0.003 (0.209)
		NAREA	57.223	0.027 (1.383)	0.018 (1.370)
		PAREA	28.561	0.039* (1.934)	-0.014 (0.954)

1. Results based on pooled time-series and cross-section data. Estimates obtained by COMTAC package available from Computer Services, ICRISAT.

Figures in parentheses are t-values; *, **, and *** indicate statistically significant at 10, 5, and 1% probability levels, respectively.

District-level estimates on these variables were available. In view of the limited number of years available for each district, data for all sorghum and pearl millet growing districts were pooled and regressions estimated for each crop, using the error components model (Wallace and Hussain 1969, Barah 1976). These equations are presented in Table 26.

The results indicated that for both the crops, the decisions on fertilizer use (ADOPTION) were significantly influenced by the credit factor and seasonal conditions during the sowing period. The average rate of fertilizer application for sorghum was similarly influenced. But the influence of these variables was found to be nonsignificant in the pearl millet equation. It was also clear that the percentage of area fertilized, particularly with nitrogen, was the main variable responding to rainfall and credit. The actual rates of application (NRATE, PRATE) were not found to be significantly affected by these variables. The results came out less strongly for pearl millet. In 7 out of 10 districts included in the analysis of this crop, the hybrids were grown under irrigated conditions (Appendix III), and this high incidence of irrigation may have reduced the effects of rainfall. The results suggest that fertilizer extension programs for these crops should be backed with adequate credit and be flexible enough to enable adjustment to seasonal conditions. It is appropriate that research recommendations on fertilizer use should now emphasize the flexibility element (Vijayalakshmi 1979, Singh 1979).

The analysis of trend in fertilizer use over time revealed that, under irrigated conditions, almost the entire area under HYV was fertilized. Under rainfed conditions, however, a significant fraction of the HYV continued to remain unfertilized even after 10 years. Also, there was considerable fluctuation from year to year. Apparently, seasonal conditions played an important role in fertilizer-use decisions—particularly decisions regarding whether to use fertilizer and what proportion of the cropped area should be covered.

Conclusions

This analysis attempted to show the status of fertilizer use on HYV of sorghum and pearl millet, the two most important cereals grown on drylands of SAT India. For sorghum, data pertaining to 21 predominantly SAT districts, and 26 districts for pearl millet were taken from the study, Sample Surveys for Assessment of High-Yielding Varieties Programme. The surveys were made by the IASRI, during 1973-74 (Raheja et al. 1976).

Data on adoption of fertilizer, and the extent and rates of fertilization for the HYV of these crops negated two popular beliefs: first, that farmers in the SAT do not use fertilizers for these low-valued, inferior cereals. The data clearly showed that in the majority of districts studied, a substantial proportion of farmers did use fertilizers for these crops; second, the data also contradicted the belief that nonirrigated millets do not receive fertilizer. The results, particularly for sorghum, showed that a majority of farmers in most of the districts used fertilizer quite extensively for the nonirrigated HYV as well. Fertilization of pearl millet hybrids was found lagging not because farmers were unwilling to use fertilizer but because the adoption of these hybrids was confined largely to irrigated lands. However, one must qualify the above influences: the spread of the HYV of these two crops has not been very high, and the local varieties which cover most of the area are largely unfertilized. Hence, it is not the low value but the lack of fertilizer responsiveness of the traditional varieties which is responsible for nonfertilization of these crops.[25]

As expected, fertilizer use varied under irrigated and nonirrigated conditions, and considerable interdistrict variation was noticed under both situations. The modal values for rates of fertilizer application (per fertilized hectare) were: 41-60 kg for N, 31-40 kg for P_2O_5, and 11-20 kg for K_2O. For irrigated pearl millet hybrids they were: 41-60 kg for N, 21-30 kg for P_20_5, and less than 10 kg for K_2O. The corresponding nonirrigated rates were: 21-40 kg for N, 21-30 kg for P_2O_5, and 11-20 kg for K_2O in the case of sorghum, and 21-40 kg, less than 20 kg, and less than 10 kg respectively, for the pearl millet hybrids. These and the data on the extent of cropped area fertilized showed better values for sorghum under nonirrigated conditions. But under irrigated conditions, the pearl millet hybrids had higher fertilizer-use indicators. Further analysis of data for eight districts over the period 1970-71 to 1976-77, and evidence from other studies indicate that although there were interyear fluctuations, the modal rates reported above were fairly firm over time.

These findings have two important implications for research on these crops. Firstly, these can be treated as benchmark levels of existing fertilization practices of farmers. A question frequently asked is: what is the fertility level against which new varieties, agronomic practices, etc., should be evaluated? The question is important because, in almost all cases, significant interactions take place between techniques and fertility levels. The estimates given above are a useful guide. Secondly, our analysis shows that there are areas where fertilizer use is quite high even under nonirrigated conditions. This implies that adaptation patterns of HYV differ, and underscores the need to develop more location-specific and fertilizer-responsive varieties. The argument is particularly relevant in the case of pearl millet, where lack of adaptation to nonirrigated conditions appears to be a major constraint.

The other important feature revealed by our analysis is that the modal rates mentioned earlier were attained within 4-5 years after the HYV were introduced. These have remained stable since. While this provides yet another evidence of the rapid response of SAT farmers to innovations, the reasons for the levels not rising over time needs to be examined. Only a detailed analysis of the data on fertilizer responsiveness of these crops will provide the answer.

Analysis of the trend in fertilizer-use parameters showed that these did not follow any systematic pattern. Comparison of data for sorghum and millets with those for rice/wheat provided some evidence of the stabilizing effect of irrigation, particularly on the area-fertilized variable. This analysis also revealed that it was important to keep all the fertilizer-use parameters—adoption, rates, and area fertilized—in perspective while studying the fertilizer-use pattern. This is an important methodological point that past studies have often ignored. It should be noted that, unlike in the case of irrigated crops where once a farmer is convinced of the advantages of fertilizer use usually stays with it, the decision whether to use fertilizer or not has to be made every time for rainfed crops. The data for irrigated districts growing pearl millet showed wider fluctuations. We argued that apart from other factors, one needs to examine the occurrence of diseases and pests in order to understand the fluctuations fully.

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25. Field experience of researchers (and our own data) suggest that farmers do sometimes apply nitrogenous fertilizers in small quantities (if the weather conditions are favorable) primarily to boost their sorghum fodder yields (Dr. N.K. Sanghi, All India Co-ordinated Research Project for Dryland Agriculture [AICRPDA], Hyderabad—personal communication). We need to take a critical look at the fertilizer-response data from this angle.

Data showing higher fertilizer use on irrigated sorghum, pearl millet, and other cereals in these districts support the hypothesis that farmers in the SAT (as elsewhere) do not lag behind in fertilizer adoption if the resulting gains were high and stable. Raheja et al. (1976) revealed that, in general, fertilization levels were higher for the irrigated superior cereals (rice or wheat) than for millets. This indicates that the farmers accorded some priority to the higher-value (and higher-response) crops while allocating their scarce irrigation and liquid capital resources. In terms of fertilizer use, therefore, the SAT presents a hierarchy of coexisting situations. To start with, there are irrigated (or nonirrigated) high-value crops which claim high priority; then follow the irrigated and nonirrigated HYV of crops like sorghum and pearl millet which respond better to fertilizer application than their local counterparts; and, at the bottom, are the large number of nonirrigated food crops which rarely figure in fertilizer-use decisions (Jha 1980).

This analysis suggests that barriers to fertilizer use on dry crops do not arise from irrationality. The traditional "reluctance" can be easily explained by the fact that most local varieties of nonirrigated (food) crops show unstable response to fertilizer application and the returns are not remunerative. Thus, development of regionally-adapted and fertilizer-responsive varieties should continue to receive the highest priority. Secondly, fertilizer use under rainfed conditions is crucially dependent on seasonal (rainfall) conditions. As such, the extension system must change from the traditional "fixed package of practices" to a highly flexible approach designed to take maximum advantage of random seasonal conditions that play such a crucial role in SAT agriculture. Finally, lack of adequate working capital also hampers fertilizer use. This emphasizes the importance of credit.

IV. Determinants of Fertilizer Use

We have gained some understanding of the major factors that determine fertilizer-use decisions. In this chapter, the issue is analyzed more rigorously. Drawing basically from microeconomic factor demand theory, several researchers have postulated that physical response to fertilizer application and prices (of inputs as well as outputs) are the major determinants of fertilizer demand (Desai 1969, Desai and Mellor 1969, and Desai et al. 1973). Aggregative analyses based on time-series data usually consider (relative) fertilizer price and irrigation as the main determinants, the latter used as a proxy for a shift in response function (Desai 1969, Parikh 1965, Patil 1978, and Rao 1973). Microlevel studies on interfarm variation in fertilizer use, on the other hand, emphasize the role of factors which influence the response function (because it is not possible to specify any single variable by directly measuring fertilizer productivity on each farm), factors which influence the adoption and diffusion of fertilizer, and factors which act as constraints on the farmers' capacity to invest in cash inputs. Prices are usually ignored because cross-sectional data do not generally permit evaluation of price effects.

We have hypothesized that fertilizer-use decisions of farmers in a given area and at a given point in time are influenced by three sets of forces: (a) the personal attributes of the farmers influence their attitudes toward fertilizers, their decisions regarding adoption, and their awareness regarding recommended levels of application, etc. Variables like education, age, risk aversion, and socioeconomic status are important in this context; (b) the resource endowments of the farmer determine his capacity to buy and effectively utilize the fertilizer input. Farm size, labor force available, capital investment in farm, differences in access to input and output markets, etc., are some relevant variables in this group; and (c) a number of agronomic and economic variables influence the response to (and profitability of) fertilizer application. Examples of such response variables are: choice of crops and varieties, soil type, moisture conditions, tenancy status, and timeliness of sowing.

It is obvious that the actual empirical model used would depend on the nature of data. For a cross-sectional study of interfarm differences in fertilizer use within a given area, only the first three would be relevant. Even here, the completeness of the model would depend on the comprehensiveness of the data in terms of agronomic and plot-specific observations. Aggregate time-series studies, on the other hand, depend mostly on macrolevel variables.

In the context of spatial variation and temporal variability, two more forces become important: (d) the institutional setting, including prevailing price regimes, market and credit; and (e) agroclimatic factors such as broad soil type, cropping patterns, rainfall, and other weather factors.

Data Source and Models

Two data sets have been used for this analysis. The first comes from the ICRISAT Village-Level Studies (Chapter II).

The second data set pertains to the IASRI study on assessment of high-yielding varieties (Chapter III). The choice of variables used in the two analyses was dictated by data availability. The model and variables used in these analyses are described in the following paragraphs.

Comprehensive farm- and plot-level data from 180 sample farmers were available from 1975 onwards. For this analysis, we have used data from 146 households over 3 years—1975-76 through 1977-78.

ICRISAT Village-level Studies data. Two approaches were employed for analyzing determinants of fertilizer demand. The first used farm-level (aggregated over plots) data and sought to identify major influences operating at this level. The second made use of plot-level observations, and enabled inclusion of some plot-specific variables also in the model. Table 27 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 = f(AGE, EDUCATION, EXPERNCE, RISKAVER,
NRATE or FARMSIZE, IRRIGATE, HHSIZE, COMCROPS,
NAREA NAREA, CREDIT, FRTPRICE, LUCK, RAIN,
RAINSQ, VDUMMY2, VDUMMY3, VDUMMY4,
VDUMMY5, YRDUMMY1, YRDUMMY2).

The plot-level analysis contained the following variables:

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

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

Table 27. Definition of variables used in regression models explaining interfarm and interplot differences in fertilizer use.

Abbreviation	Expected relationship	Analysis	Variable specification
Dependent variables			
1. AVNPK	-	Farm/plot	Total plant nutrients ($N+P_2O_5+K_2O$) used on the farm or plot (kg/ha).
2. NRATE	-	Farm/plot	Rate of nitrogen application (kg/ha fertilized) on the farm or plot.
3. NAREA	-	Farm	Percent of cropped area fertilized with nitrogenous fertilizers.
Explanatory variables			
I. Personal characteristics			
1. AGE	$b < o$	Farm/plot	Age, in years, of the head of the farm household.
2. EDUCATION	$b > 0$	Farm/plot	Education of the head of the household expressed as score based on years of formal education.
3. EXPERNCE	$b > 0$	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 1980).[1]
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 of irrigable area on the farm. Dummy variable with value 1 for irrigated plots.
7. HHSIZE	$b > o$	Farm/plot	Number of family members.
8. SOILDMY1	$b > o$	Plot	Dummy given value 1 for plots on deep black soils.[2]
9. SOILDMY2	$b > o$	Plot	Dummy given value 1 for plots on medium-deep black soils.

Continued.

Table 27 continued.

Abbreviation	Expected relationship	Analysis	Variable specification
10. PURECROP	b > o	Plot	Dummy given value 1 if sole crop was sown on the plot and 0 if mixed crops were sown.
11. OWNPLOT	b < o	Plot	Dummy given value 1 for leased-in plots, and 0 for owned plots.
12. HYVDMY	b > o	Plot	Dummy given 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	Percent of area under commercial crops in the farm.[3]
14. CREDIT	b > o	Farm/plot	Total borrowings, in rupees, of the farmer during the year.[4]
15. FRTPRICE	b < o	Farm/plot	Price paid, in rupees, per kg of plant nutrient by the farmer.[5]
16. PROPRICE	b > o	Plot	Lagged average village price, in rupees per 100 kg, of the crop grown on the plot.
IV. Agroclimatic factors			
17. RAIN	b > o	Farm/plot	Rainfall, in mm, during June to November (or June to August) in the village.
18. RAINSQ	b < 0	Farm/plot	Square of the above rainfall variable.
19. VDUMMY1		Farm/plot	Dummy variable for Aurepalle village (Nahbubnagar).
20. VDUMMY2		Farm/plot	Dummy variable for Dokur village (Nahbubnagar).
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).

Continued.

Table 27 continued.

24. YRDUMMY1	Farm/plot	Dummy variable for 1975-76.
25. YRDUMMY2	Farm/plot	Dummy variable for 1976-77.

Source: Based on ICRISAT VLS data for the years 1975-76 to *77-78.*

1. 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.
2. 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.
3. The crops considered were sugarcane, vegetables, cotton, groundnut, and castor.
4. This variable was defined to include 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.
5. Where only straight fertilizers were used, the calculation of price per kg of nutrient was easy. But where mixtures or complex fertilizers (containing more than one nutrient) were used, the calculations were more 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.

IASRI data. The survey (see Chapter III for details) covered 21 districts for sorghum, and 26 districts for pearl millet. Plotwise data for each district from the Yield Estimation Survey for 1973-74 were used for this analysis. In each district, 80 fields (plots) growing HYV were chosen for the crop-cutting experiments, and information was gathered on the major inputs used on each plot.[26]

The variables used in this analysis are given in Table 28. As can be seen, the main set of variables related to plot-specific conditions, although farm-size and fertilizer price were fajrm-specific. The following regression model was estimated for each district:

AVNPK or = f(SOILDMY, DRAINAGE, TIMLYSOWN, PREVCROP,
NRATE or RAINFALL, FRTPRICE, FARMSIZE)
PRATE

It can be seen that the two data sets were, in a sense, complementary. It was hoped that by integrating the results of the two analyses, it would be possible to obtain a better understanding of the decisions of farmers regarding fertilizer use.

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[26] Scrutiny of data for each district revealed that information on fertilizer prices was not collected for plots where no fertilizers were used. Such observations were deleted for purposes of this analysis. Also, no regressions were estimated for districts where the number of fertilized plots was less than 20.

Table 28. Definition of variables used in regression models explaining interplot differences in fertilizer use: IASRI districtwise data.

Abbreviation	Expected relation-ship	Variable specification
Dependent variable		
1. AVNPK		Total plant nutrients ($N+P_2O_5+K_2O$) used on plot (kg/ha fertilized).
2. NRATE		Rate of application of nitrogen (N) used on plot (kg/ha fertilized).
3. PRATE		Rate of application of phosphorus (P_2O_5) used on plot (kg/ha fertilized).
Explanatory variables[1]		
1. SOILDMY	b>o	Dummy variable for heavier-textured soil.
2. DRAINAGE	b<o	Dummy variable for poorly-drained or waterlogged plots.
3. TIMLYSON	b>o	Dummy variable for plots sown at normal time.
4. PREVCROP	b<o	Dummy variable for plots sown with commonly fertilized or legume crops in the preceding season.2
5. RAINFALL	b>o	Dummy variable for adequacy of rainfall during the crop season.
6. FRTPRICE	b<o	Price paid by the farmer, in rupees, per kg of plant nutrient.3
7. FARMSIZE	b<o	Size of the operational holding of the farmer in hectares.

1. Variables 1, 2, 3, and 5 were qualitatively measured in terms of opinion of the farmer concerned.
2. This dummy variable took the value unity if sugarcane, tobacco, cotton, vegetables, high-yielding varieties of cereals, and groundnut or a legume crop was grown in the preceding season.
3. See footnote 5, below Table 27.

Results

The results obtained from farm-level analyses in ICRISAT Village-Level Studies are summarized in Table 29, and plot-level analyses in Table 30. Results of districtwise regressions, estimated from IASRI data are summarized in Table 31. The estimated regression equations have not been presented here.[27] For brevity, the results are discussed in terms of variables and only general tendencies are indicated.

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[27] See Jha and Sarin 1981 for VLS-based regressions and Jha et al. 1981 for IASRI results.

Table 29. Variables influencing interfarm variation in fertilizer use.[1]

Variables	AVNPK				NRATE				NAREA			
	Pooled	Sholapur	Akola	Mahbubnagar	Pooled	Sholapur	Akola	Mahbubnagar	Pooled	Sholapur	Akola	Mahbubnagar
I Personal factors												
AGE												
EDUCATION												
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)	(-)		(+)				(+)			(-)	(+)	

Source: Based on ICRISAT VLS data for the years 1975-76 to 77-78.

1. See Jha and Sarin 1981, for regressions.
b = variable not included in the equation.
(+) indicates positive relationship.
(-) indicates negative relationship.

Table 30. Variables explaining interplot variation in fertilizer use.[1]

Variables	AVNPK				NRATE			
	Pooled	Sholapur	Akola	Mahbubnagar	Pooled	Sholapur	Akola	Mahbubnagar
I Personal factors								
AGE					(+)			
EDUCATION	(+)			(+)	(+)			(+)
EXPERNCE	(+)		(+)	(+)	(+)		(+)	
RISKAVER		(-)		(+)		(-)		(+)
II Plot and 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)	(-)							

Source: Based on ICRISAT VLS data for the years 1975-76 to 77-78.

1. See Jha and Sarin 1981, for regressions.
b = variable not included in the equations.
(+) indicates positive relationship.
(-) indicates negative relationship.

Table 31. Variables explaining interplot variation in fertilizer use on high-yielding varieties of sorghum and pearl millet: IASRI, 1973-74 data.[1]

District (State)	Dependent variable	SOIL-DMY	DRAIN-AGE	TIMLY-SON	RAIN-FALL	PREV-CROP	FRT-PRICE	FARM SIZE
				A.Sorghum districts				
Jalgaon (Mah)	AVNPK					(+)	(+)	
	PRATE					(+)	(+)	(-)
Ahmadnagar (Mah)	AVNPK	(+)				(+)	(+)	
	NRATE		(+)					
Osmanabad (Mah)	AVNPK					(-)	(+)	
	NRATE					(-)		
Nagpur (Mah)	AVNPK	(+)				(-)		
	NRATE	(+)	(-)	(+)		(-)	(-)	
	PRATE	(+)				(-)		
Belgaum (Kar)	AVNPK				(+)			
	NRATE				(+)			
Akola (Mah)	AVNPK		(+)			(+)		
	NRATE						(-)	
	PRATE					(+)		(+)
Buldhana (Mah)	AVNPK			(+)	(-)			
	NRATE	(+)		(+)	(-)			
	PRATE			(+)				
Amaravati (Mah)	AVNPK							(-)
	NRATE							(-)
	PRATE	(+)			(+)			
Bellary (Kar)	AVNPK				(+)		(-)	
	NRATE				(+)		(-)	
	PRATE				(+)		(-)	
Satara (Mah)	AVNPK	(-)					(-)	
	NRATE	(-)	(+)	(+)		(-)	(-)	
	PRATE	(-)			(-)		(-)	
Nanded (Mah)	AVNPK			(-)				
Parbhani (Mah)	AVNPK				(+)			(+)
	NRATE	(+)			(+)	(-)	(-)	(+)
	PRATE				(+)			
Mandsaur (MP)	AVNPK	(+)						
	NRATE	(+)				(+)	(+)	
	PRATE							(+)
Anantapur (AP)	AVNPK	(-)			(-)			(-)
	NRATE	(-)	(+)		(-)	(-)	(-)	(-)
Sangli (Mah)	AVNPK				(+)			
	NRATE			(-)		(+)	(-)	
	PRATE	(+)					(-)	
Shimoga (Kar)	AVNPK			(-)	(+)		(-)	
	NRATE			(-)	(+)		(-)	
	PRATE				(+)		(-)	
Shimoga (Kar)[2]	AVNPK					(+)	(-)	(+)
	NRATE	(-)			(+)	(+)	(-)	(+)
	PRATE	(-)				(+)	(-)	

Continued.

Table 31 continued.

District (State)	Dependent variable	SOIL-DMY	DRAIN-AGE	TIMLY--SON	RAIN-PALL	PREV-CROP	FRT-PRICE	FARM SIZE
				B.Pearl millet districts				
Nellore (AP)	AVNPK							(+)
	NRATE							(+)
	PRATE						(-)	
Tirunelveli (TN)	AVNPK							(+)
	NRATE			(+)				(+)
	PRATE							(+)
Jalgaon (Mah)	AVNPK	(+)			(-)			
	NRATE				(-)		(-)	
	PRATE			(+)				
Coimbatore (TN)	AVNPK	(+)				(-)		
	NRATE	(+)				(-)	(-)	
	PRATE	(+)						
Chingleput (TN)	PRATE					(-)		
Rohtak (Har)	AVNPK				(+)	(-)		
	NRATE				(+)	(-)	(-)	
Morena (MP)	AVNPK				(+)	(+)		
	NRATE						(-)	
	PRATE					(+)		
Parbhani (Mah)	AVNPK	(+)	(-)	(+)			(-)	
	NRATE	(+)	(-)	(+)	(+)	(-)	(-)	
	PRATE	(+)		(+)				
Jaipur (Raj)	AVNPK				(+)		(+)	
	NRATE				(+)			
Guntur (AP)	NRATE			(+)				
	PRATE			(+)	(-)		(-)	
Chittoor (AP)	AVNPK				(-)			
	NRATE				(-)		(-)	
Hissar (Har)	AVNPK			(+)		(-)		(+)
Bellary (Kar)[2]	AVNPK			(-)	(+)			
	NRATE				(+)			(+)
	PRATE		(-)	(-)	(+)		(-)	
Madurai (TN)[2]	AVNPK			(+)	(-)			
	NRATE			(+)	(-)			
	PRATE				(-)			
Coimbatore (TN)[2]	AVNPK	(+)						
	NRATE			(+)	(-)			
	PRATE	(+)		(+)				

1. See Jha et al. 1981, for regressions.
2. Postrainy-season crop.
(+) indicates positive relationship.
(-) indicates negative relationship.

Personal characteristics. Personal traits of the farmer assume particular significance in the context of use of modern inputs in farming. This set of variables could be considered on the VLS-based analysis. The plot-level regressions (Table 30) provided better results in this regard. The results indicated that farmers with higher education and longer experience used higher levels of fertilizer. 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 the Sholapur region, the hypothesized effect was noted, and fertilizer rates were found to be negatively related to the degree of risk aversion (Table 30). The plot-level equations for Mahbubnagar appeared inconsistent. In the farm-level regressions (Table 29), the effect of this variable showed up on the fertilized-area variable in two out of four equations and also on the rate of application of nitrogen in the Sholapur region. It thus appears that in relatively unstable areas (like Sholapur), risk aversion did deter fertilizer use. In other areas, this effect did not seem so important.

Resource endowment and plot-level factors. The farm-level regressions (Table 29) showed that the average level of fertilizer application and the extent of cropped area fertilized were lower on larger farms. This effect was pronounced in the Akola and Mahbubnagar regions. The regressions in Table 30 showed a similar influence on the rate of fertilizer application on pooled data but, in the regional equations for Mahbubnagar and Akola, this variable was not found to be significant. In the Sholapur region, there was some indication of a positive relationship between farm size and rate of fertilizer application.

In the equations for districts growing sorghum and pearl millet (Table 31), the results were not consistent with regard to farm size. In 18 equations, this variable was found to be significant, and in 13 it had a positive sign. The hypothesis that farm size has a negative influence on fertilizer use was based on the logic that due to greater pressure to employ land-augmenting practices, smaller farms would have more input-intensive cultivation. One must note, however, that this variable could also be interpreted as a proxy for socioeconomic status and the capital position of the farmer, both of which are likely to be positively related to fertilizer use. This interpretation is perhaps more appropriate with regard to the IASRI analysis, because variables measuring these attributes (such as education and credit) were not explicitly included. One thus needs to interpret the results pertaining to this variable carefully. On the basis of the more completely specified model used on the ICRISAT VLS data, one can conclude that the effect of farm size was negative. A positive influence could also arise in areas like Sholapur where fertilizer use was a relatively recently-adopted practice. During the initial phase of adoption such a relationship is more likely.

The household-size variable was considered in the VLS regressions as an indicator of higher subsistence pressure, better availability of labor, and better access to and exchange of information—all hypothesized to exert a favorable influence on fertilizer use. The results (Tables 29 and 30), however, were not clear. Both farm- and plot-level regressions revealed a positive influence on rates of fertilizer application, but in the area-fertilized regressions, the coefficients turned out to be negative in 2 out of 4 equations (Table 29).

Irrigation, as expected, was found to exercise a strong positive influence on fertilizer use. Its effect was more pronounced on fertilization rates in the plot-level regressions (Table 30) because this variable was specified more directly in this analysis.[28] The coefficients of this variable in the Mahbubnagar rate equations (Tables 29 and 30) were not significant, probably because of the lack of variability: almost all fertilized plots were irrigated in this region. Thus the results clearly indicated that irrigation strongly influenced decisions regarding actual rates of application, although its effect

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[28] In the farm-level analysis, average irrigation availability on the farm was considered, whereas in the plot-level analysis the status of this variable in the plot actually fertilized was specified.

on fertilized area was also significant (Table 29). Interestingly, the irrigated rates were found to be higher in Akola also? Table 13 (Chapter II) had not revealed this tendency clearly.

Equally interesting were the findings on the influence of factors depicting the agronomic conditions of the plots actually being fertilized. There was an indication (Table 30) that black soils were fertilized at higher levels than other soil types. This trend was noted in the Akola and Mahbubnagar regions. The nitrogen-rate equation in Sholapur, perhaps because of the preponderance of black soils in this region, carried an inconsistent sign.

The IASRI analysis looked at the impact of the textural status of the soil on fertilization rates. This variable was found to be significant in 26 equations, and in 19, it had the hypothesized signs. This indicated that, generally, crops grown on heavier-textured plots were fertilized at higher rates. In some districts (Satara, Anantapur, and Shimoga), a negative influence was observed. One would need more detailed specifications of the soil conditions to explain these apparent inconsistencies. In sum, the results of both the analyses indicated that soils (and plots) with higher moisture-retention capacity were fertilized at higher rates. This highlights the crucial importance of soil-moisture conditions in the context of fertilizer-use decisions in the SAT.

An attempt was made to test the hypothesis that farmers' decisions were also influenced by the drainage condition of the plot and that poorly-drained plots were fertilized at lower levels. This variable was not found to be significant in most of the districts (Table 31); even in the eight equations where it was found significant, the signs were erratic. It may be noted that, generally, neither sorghum nor pearl millet was grown on plots prone to waterlogging, and this might have been the reason for indifferent response to questions on drainage. The results do not permit any conclusions regarding the influence of this variable.

The VLS regressions (Table 30) did not show any influence of plot ownership and high-yielding varieties on fertilizer-use decisions. While the former can be explained by the very limited number of leased-in fertilized plots, the latter finding was surprising and went against the accepted view. The high-yielding varieties have been shown to be more fertilizer consuming (NCAER 1978) in all studies. The 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.

Timeliness of sowing was also hypothesized to influence fertilizer use positively. Farmers were assumed to be aware that late sowing causes lower yields and, therefore, lowers the effectiveness of fertilizers. This variable was statistically significant in 9 equations for sorghum and in 14 for pearl millet (Table 31), and seemed to positively influence fertilization rates. The evidence showed up relatively more strongly for pearl millet. In the case of sorghum, the signs were inconsistent in 4 out of 9 equations.

Previous fertilization history of the plot was assumed to have been taken into account while making current fertilizer-use decisions (IASRI analysis). It was hypothesized that plots fertilized in the previous season would receive relatively lower importance in the current season. This variable also fared relatively better in the districts growing pearl millet (Table 31). For sorghum, the results were mixed. Obviously, the rather weakly-specified nature of this variable affected the results obtained. Nevertheless, there was an indication that this variable entered the farmers' decision-making process.

We hypothesized that the nature of crop grown (sole or mixed) also influenced fertilizer-use decisions, and that mixed crops were fertilized at lower rates as compared to sole crops (Table 14). The VLS regression results supported this hypothesis and in the pooled as well as in the Akola equations (Table 29), this variable was found to be significant. It may be recalled that it was only in Akola that mixed crops claimed a significant share of the total fertilizer used.

Institutional factors. Credit was hypothesized as a major constraint on fertilizer use. This variable was considered in the VLS regressions (Tables 29 and 30). It emerged significant in only a few farm-level regressions (Table 29); the plot-level analysis (Table 30) did not show this variable to be significant in any case. The results thus did not reveal this variable to be overwhelmingly important. However, it should be noted that this variable was specified as the total borrowings of the farmer, irrespective of the use they have been put to. This specification might have led to the indifferent results obtained for this variable. It may be recalled that in regressions explaining interregional variation in fertilizer adoption and use on high-yielding varieties of sorghum and pearl millet (Chapter III, Table 26), credit emerged as an important variable. In this analysis, credit was specified as the actual level of borrowings for agricultural purposes. A number of studies (NCAER 1978, Maharaja 1975, and Jha and Sarin 1981) have shown that inadequacy of capital plays an important restrictive role in adoption and use of fertilizers.

The extent of commercialization was also hypothesized to positively influence fertilizer use. In almost all the VLS equations, the variable had the wrong sign (Tables 29 and 30). These results also stemmed from poor specification. It may be recalled that area under commercial crops such as cotton, groundnut, castor, sugarcane, and vegetables was used to depict this variable. Sugarcane and vegetables were quantitatively nonsignificant, and the rest were primarily rainfed crops with lower fertilizer-use values. This variable thus appeared to capture the effects of irrigation (or lack of it) more strongly than commercialization.

Of the two price variables considered, produce price did not emerge as significant in any plot-level VLS regression (Table 30). Since plots growing different crops were pooled in this analysis, we expected a positive coefficient for this variable to support the hypothesis that high-value crops were fertilized at higher rates. The results indicated that it was a poor proxy for profitability of fertilizer application.

Fertilizer price, on the other hand, had the expected sign in most equations where it was significant (Tables 29, 30, and 31). Exceptions were the farm-level VLS regressions (Table 29) which showed this variable to be positively related to average rate of fertilizer application. But in this case also, the signs were as expected for the nitrogen rate equations. In the IASRI analysis (Table 31) this variable emerged significant in 40 equations and the signs were as expected in all but six of these equations. The fact that we were able to identify price effects from cross-sectional data sets suggested the existence of interfarm price differentials. We consider it a major contribution because almost all studies based on cross-sectional data assume that such variations do not exist and, accordingly, do not include a price variable in the model. It should be noted that in our specifications, price variation could arise from two sources (apart from a temporal element in the VLS data): interfarm differences in prices paid for the same fertilizer material, and use of different fertilizer materials (mixtures or complex fertilizers) which leads to different prices for individual nutrients, depending on the weights these nutrients carry in the total fertilizer mix. Significant coefficients for this variable implied that farmers were aware of this subtle price differentiation phenomenon and responded rationally to changes in real prices of fertilizer nutrients. This finding has implications for retail trade in fertilizers. We shall come back to this later.

Agroclimatic factors. The most important result under this set of variables pertained to the influence of rainfall on fertilizer-use decisions. The VLS farm-level regressions (Table 29) revealed that rainfall was an important determinant of decisions regarding rates as well as extent of cropped area fertilized. Because of limited variation of the dependent variable, the relationship between agroclimatic changes and fertilizer use was not statistically significant. These equations also indicated that very high rainfall adversely affected nitrogen use and that the effect was more important in the low-rainfall areas (Sholapur and Mahbubnagar).

A different approach was employed in the IASRI district-level analysis that used farmers' opinions regarding adequacy of rainfall as the explanatory variable. The results (Table 31) indicated that adequacy of rainfall during the cropping season positively influenced fertilizer use on sorghum. Out of 19 equations in which this variable was found to be significant, 14 carried the hypothesized sign. Results were inconclusive for pearl millet, perhaps because pearl millet hybrids were more frequently grown under irrigated conditions. It may be recalled that a similar phenomenon was observed (Table 26) in regressions based on 4 years' data.

The significance of village and year dummies in the VLS regressions (Tables 29 and 30) emphasized the location- and time-induced variability in fertilizer use. Several factors that we could not specify in our models could be responsible for this. For example, seasonal occurrence of pests and diseases, availability of fertilizer, access to markets, and the fertilizer-distribution network may all affect fertilizer use. Some of these cannot be adequately specified in microlevel models.

We will now look at interregional variability. Here, the VLS analysis is more relevant since the necessary background data on the areas studied are available.

Fertilizer use was lowest in the Sholapur region. The regressions indicated that fertilizer use in this region was primarily determined by soil moisture. Irrigation and rainfall during the growing period were the primary determinants. There was also an indication that the variables, risk aversion and experience, influenced decisions regarding rate of fertilizer application. These results are consistent with the high-risk environment that characterize 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 to be a significant variable in any equation for this region. It may be recalled that this region received relatively higher and more stable rainfall than the other regions studied.

In Mahbubnagar, fertilizer use was confined to irrigated crops. Farmers who used more irrigation also used more fertilizer. 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.[29]

Conclusions

Multiple-regression analysis was used on ICRISAT Village-Level Studies data and on data obtained from IASRI to identify major factors influencing fertilizer-use decisions. The basic model employed hypothesized that personal characteristics, resource endowments, actual cultivation conditions, and institutional and agroclimatic factors were the broad influences operating on farmers' decisions regarding rates of application and extent of cropped area fertilized.

The results of these analyses indicated that soil moisture was the most important determinant of fertilizer use in the semi-arid tropics. Areas and farms with well-developed irrigation showed higher fertilizer use. In the low-rainfall areas, fertilizer use was influenced by rainfall. The importance of extension of irrigation is obvious. Evidence on adjustments made by farmers to changes in seasonal rainfall has an important implication for extension programs, particularly in areas having low and unstable rainfall. The general practice of making a fixed, single-valued recommendation regarding fertilizer use is clearly unrealistic. Farmers should be presented with a more flexible package of recommendations that would help them minimize the chances of large capital loss in the event of unfavorable weather and yet provide for strategies that will enable them to make technically optimal decisions depending on seasonal conditions as they unfold. The role of an effective extension service was also emphasized by the significance of the knowledge variables in the regressions.

Results with respect to plot-specific characteristics clearly indicated that the expected response to fertilizer application was an extremely important determinant of fertilizer use. The rates were found to be higher on plots having better moisture-retention capacity, plots growing sole rather than mixed crops, and on plots sown at the right time. All these indicated that farmers in the SAT are becoming conscious of the finer points of fertilizer-use technology. The farmers were also found to make adjustments in response to changes in seasonal rainfall conditions. This reflects their enterprise and signifies a rational approach in a situation where the status of the most critical production input—soil moisture—is uncertain.

Risk aversion was found to be an important determinant of fertilizer use in the low-rainfall, unstable regions. In the other regions it was not important. This suggested that this variable was not a universal deterrent to fertilizer use in the SAT. Where the environment itself was highly risky, the variable assumed significance. Experience with fertilizers, and education—both

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[29] A separate analysis was also carried out to model the decision on fertilizer adoption for the 144 households who were in the VLS sample for 3 consecutive cropping years from 1975-76 (Binswanger et al. 1982). Irrigation intensity and household wealth were the most important considerations in fertilizer adoption. Village dummies also exhibited a strong effect on adoption. However, no personal characteristic had a statistically significant influence on the adoption decision. The weak impact of personal characteristics on fertilizer adoption is probably due in part to the necessity of irrigation to achieve a positive payoff from fertilizer (only about half of the households had access to irrigation). That risk-aversion had no effect on fertilizer adoption may be related to the composition of the different constituents/ elements used as fertilizer. Even a farmer who views investment in fertilizer as risky could experiment with it on a small plot for a minimal commitment of funds.

indicators of the level of farmers' knowledge—were the other personal characteristics which influenced fertilizer use.

Fertilizer prices and credit emerged as important institutional factors influencing fertilizer-use decisions. Several researchers have emphasized the constraint imposed by capital scarcity. Institutional financing is now being accorded a high priority in development programs. Evidence on the significance of the price variable suggested the presence of cross-sectional price variation despite fertilizer prices being statutorily fixed. It is doubtful that these arise from transportation costs alone. We believe that imperfections in the retail trade (which restrict access and limit availability of the right kind of fertilizer materials at the proper time) compel farmers to purchase fertilizer at different prices depending on the fertilizer mix available in the market. Thus, from the point of view of policy, significance of the price variable indicates the need for improvement in the retail trade of fertilizers by increasing the number of retail points, timely availability of the right kinds of fertilizer, free access to fertilizer credit, etc.

V. Summary and Implications

Summary

The structural profile of fertilizer consumption in the country indicates that the irrigated lands claim most of the fertilizer used in the Indian SAT. There is some use of fertilizer on dryland crops in areas receiving relatively high rainfall, but in the low-rainfall regions, fertilizer use is almost entirely confined to irrigated crops. Irrigated farming has provided the main source of growth in fertilizer consumption throughout the 1960s and 1970s. This trend is likely to continue because a considerable fraction of the irrigated area is still unfertilized, and future efforts toward intensification of agriculture will obviously involve exploitation of this slack.

In areas where irrigation facilities are meagre and creation of new irrigation potential costly—the situation in most of peninsular India—use of fertilizers on nonirrigated lands depends on adequacy and stability of rainfall and the resultant stability of responses and fertilizer responsiveness of different crops. Areas and crops favourably endowed in this regard are likely to show accelerated growth in fertilizer consumption. These tendencies can clearly be inferred from the analyses presented in the preceding chapters.

The distinction between irrigated and nonirrigated situations is crucial: the production patterns, intensity of input use, and the problems are all different. It is perhaps more important to recognize that this distinction is not geographic. Irrigated and nonirrigated plots exist side by side and each farmer usually possesses both kinds. This integration calls for choices, not only with regard to fertilizer but with respect to all inputs. Farmers accord priority to the higher-value (and higher response) crops in allocating their scarce irrigation and liquid capital resources.

Profitability of fertilizer application and assurance of response have been the major forces motivating fertilizer use in the Indian SAT. This leads to emphasis on irrigated crops, commercial crops, and high-response varieties of nonirrigated crops. Traditional, low-response varieties of cereals and pulses, which occupy a bulk of the cropped area, are usually not fertilized. The importance of assured returns can be appreciated from the fact that farmers do not use fertilizer under nonirrigated conditions in low-rainfall areas (where soil-moisture status is low and uncertain); even in relatively high-rainfall areas, fertilizer use is higher on soils having relatively high moisture-retention capacity. Farmers show their awareness of the status of soil moisture by adjusting their fertilizer use according to occurrence of rainfall. Hence, in the highly (monsoon) unstable regions like Sholapur, they do not usually apply fertilizer to rainfed crops in the rainy season, but prefer to wait till the status of soil moisture is known with relative certainty in the postrainy season.

These phenomena largely explain the observed adoption and diffusion pattern of fertilizer use in the Indian SAT. Fertilizer use in the nonirrigated SAT commenced in earnest only after the mid-1960s, when fertilizer-responsive varieties became available. The pace of diffusion has since been rapid in areas where the certainty conditions have been favourable; in others, it has been tardy and uncertain, characterized by intermittent rather than continuous use. Moreover, these are the areas that pose the most serious challenge for agricultural research.

The importance of fertilizer responsiveness was clearly brought out by the analysis for high-yielding varieties of sorghum and pearl millet—the two major food-grain crops grown on the drylands of SAT India. Farmers do use fertilizer on these low-value, nonirrigated crops also, provided the responses are attractive. It is lack of fertilizer-responsiveness that is the major barrier from the technological point of view.

We have presented considerable evidence to show that farmers are conscious of the technical efficiency of fertilizer use. Their fertilizer use decisions are influenced by factors such as relative response to fertilizer application, timeliness of sowing, soil type, and seasonal rainfall conditions—all of which have an important bearing on the efficiency of fertilizer use. This indicates the growing maturity of SAT farmers. The evidence also shows that there is scope for improvement in this regard, particularly in the context of balanced use of plant nutrients and timing of fertilizer application. These practices should be emphasized in the extension programs. In this context, it is also relevant to note that relatively few fertilizer users really know about specific recommendations regarding fertilizer use, particularly for nonirrigated crops. These weaknesses in the extension programs need to be removed. Our results revealed that knowledge—represented by farmers' experience with fertilizer and education—is an important determinant of fertilizer use. Extension has a crucial role to play in this regard.

Risk aversion is often believed to be a reason for nonadoption or low level of fertilizer use. Our analysis indicates that this variable is important only in the relatively low- and unstable-rainfall areas, that is, areas where the inherent environmental risk is high.

Credit and fertilizer prices were identified as important institutional factors. Capital rationing (coupled with problems of availability) restricts outlay on fertilizers below optimum requirements, and this is manifest in lower spread of fertilizers in terms of area and crops covered (even on irrigated lands) and in lower rates of application. In our analysis interfarm variation in fertilizer prices were mainly due to imperfections in the fertilizer-distribution system. The results indicate that removal of these imperfections will result in higher fertilizer use. These findings highlight how institutional improvements can promote fertilizer use and raise crop productivity.

Implications for Agricultural Research

1. Research on soil-moisture management must be accorded high priority. Adoption and use of modern inputs in SAT agriculture depends on assurance of returns. Water is the most important determinant of stability in crop production.

2. Results for the low-rainfall regions reveal that farmers adjust nitrogen use according to changing soil-moisture conditions, brought about by the quantity and distribution of rainfall during the crop-growth season. How most efficiently to achieve this is another question which needs careful research.

3. Emphasis on fertilizer responsiveness must continue in crop-improvement research. Pulses and oilseeds deserve special attention in this regard. This also appears relevant for pearl millet hybrids under rainfed conditions.

4. It would be useful to classify the SAT according to adequacy of rainfall for rainfed-farming areas, and initiate relevant programs of research for each category. The Akola and Sholapur situations illustrate this clearly. In the low- and unstable-rainfall regions, crop-improvement and agronomic research should aim at evolving technologies which provide high returns under adverse soil-moisture conditions. In fact, research programs should be confined to such areas. The SAT production environment is highly diverse and this diversity must be reflected in the research strategy.

5. Crop improvement and management research for nonirrigated crops should be evaluated at relatively lower fertility conditions. Indeed, there is an urgent need to evaluate the fertilizer-response data for rainfed crops to ascertain whether the recommended levels are indeed optimal under a risky environment.

Implications for Extension and Development Programs

1. Extension agencies have so far concentrated on irrigated crops. Our results indicate that providing more information about improved dryland agriculture would have significant payoffs.

2. No distinction other than level of application is usually made in recommendations regarding fertilizer use under irrigated and nonirrigated conditions. The results indicate the need for a flexible recommendation package for rainfed crops which would enable farmers to adjust optimally to changing seasonal conditions. This aspect is well accepted by research workers, but the extension agencies have not taken it up in earnest. This would also call for more dynamism in the extension services and use of rapid-spread extension mass media tools.

3. Credit was identified as a very important constraint, underscoring the need to strengthen and expand the institutional credit infrastructure in the SAT.

4. Improvements in the fertilizer-distribution structure and the fertilizer-credit policies have an important bearing on fertilizer-use decisions of the farmers. The need for an increase in the number of retail outlets and timely availability of the right kinds of fertilizer is indicated. The fertilizer-credit policy can play an important role in achieving balanced use of fertilizers. This aspect needs to be studied.

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Appendix I. Relative performance of districts recording high* growth in fertilizer consumption in the 1960s and 1970s.

SAT category	Growth in: 1970s	Growth in: 1960s	Name of the district
			NITROGEN
Nonirrigated	H	H	Nasik, Dhulia, Jalgaon, Kurnool, and Kaira.
	H	M	Ahmadnagar, Satara, Sangli, Kolhapur, Mysore, Bellary, Belgaum, Raichur, Mahbubnagar, Nalgonda, Baroda, Mehsana, Surat, and Rajkot.
	H	L	Khammam, Allahabad, Mirzapur, Sabarkanta, Kheri, Bahraich, and Hardoi.
	M	H	Gonda and Buldhani.
Irrigated	H	H	Guntur, Nizamabad, S. Arcot, N. Arcot, Coimbatore, Tiruchirapalli, Madurai, Moradabad, Rae-Bareily, Thanjavur, E. Godavari, W. Godavari, Mandya, Gurdaspur, Amritsar, Jullunder, Ludhiana, Patiala, Ambala, Kurukshetra, Muzaffarnagar, Meerut, Bulandshahr, Gorakpur, and Deoria.
	H	M	Warangal, Karimnagar, Chingleput, Aligarh, Mainpuri, Budaun, Varanasi, Kapurthala, Saharanpur, Bijnor, and Jaunpur.
	H	L	Agra, Bareily, Shahjahanpur, Rampur, Ghazipur, Ballia, Shimoga, and Karnal.
	M	H	Cuddapah, Faizabad, Basti, Hoshiarpur, Krishna, and Ropar.
			PHOSPHORUS
Nonirrigated	H	H	Dhulia, Jalgaon, Ahmadnagar, Kolhapur, Kurnool, Junagarh, Rajkot, and Amreli.
	H	M	Chitradurg, Bellary, Dharwar, Belgaum, Raichur, Mahbubnagar, Nalgonda, Surat, and Bhavnagar.
	H	L	Mysore, Khammam, Sabarkanta, and Hassan.
	M	H	Nasik, Buldhana, and Satara.
	L	H	Poona and Sangli.
Irrigated	H	H	Krishna, Guntur, Nizamabad, N. Arcot, Coimbatore, Thanjavur, E. Godavari, W. Godavari, Mandya, Amritsar, Kapurthala, Jullunder, Ludhiana, and Gorakhpur.
	H	M	Warangal, Karimnagar, Madurai, Aligarh, Etah, Farrukhabad, Varanasi, Shimoga, Gurdaspur, Hoshiarpur, Patiala, and Karnal.
	H	L	Agra, Mainpuri, and Ghazipur.
	M	H	Bulandshahr, Tiruchirapalli, Salem, S. Arcot, Chingleput, Muzaffarnagar, and Deoria.
	L	H	Basti and Meerut.

*The growth categories (classification based on annual increment in consumption measured in t) were:

	N	P_2O_5
High (H)	>750	>300
Medium (M)	301-750	101-300
Low (L)	<300	<100

Note: The position for the 1960s was read from maps 3.1 and 3.2 in Desai and Singh (1973). Since the maps were not very legible/ some marginal errors in growth categories for the 1960s are likely.

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

Region/District/ Village	Major soil type[1]	Normal annual rain-fall (mm)[1]	Major crops grown in the villages[1]	Average size of holding[2] (ha)	% of irriga-ted area[2]	Cropping inten-sity[2] (ha)	Area per family[1] worker (ha)	Area per bullock pair[1] (ha)
I Sholapur (Maha-rashtra)								
1. Kalman	Medium-deep Vertisols	660	Sorghum (post-rainy), wheat, pigeonpea, chickpea, and minor pulses	8.5	10	108	2.3	13.3
2. Shirapur	Medium-deep Vertisols	636	Sorghum (post-rainy), wheat, pigeonpea, chickpea, and minor pulses	6.5	13	119	1.2	10.0
II Akola (Maha-rashtra)								
1. Kanzara	Medium-deep Vertisols	819	Cotton, sorghum, mungbean, wheat, and groundnut	6.5	5	103	1.1	8.0
2. Kinkheda	Medium-deep Vertisols	819	Cotton, sorghum, mungbean, wheat, and groundnut	6.7	4	106	2.1	8.0
III Mahbubnagar (Andhra Pradesh)								
1. Aurepalle	Deep Alfisols	681	Sorghum, paddy, castor, pearl millet, and pigeonpea	5.6	21	114	1.3	5.0
2. Dokur	Medium-deep Alfisols gravelly	762	Paddy, groundnut, sorghum, pigeon-pea, and castor	3.7	60	113	0.8	3.8

Source: 1. Jodha et al. 1977.
2. Jodha 1979.

Appendix III. Important agroeconomic features of selected districts (1973-74).

District (State)	Normal annual rainfall (mm)	Major soil type	% of area under sorghum/ pearl millet	% of cropped area under HYV 1973-74	% of HYV area under irrigation 1973-74	Dominant HYV in 1973-74	Fertilizer consumption (kg/ha)[1]	Number of cultivators in the AAE sample
1	2	3	4	5	6	7	8	9
			A. Sorghum districts					
Jalgaon (Mah)	741	MDB	18	38	44	CSH 1	26.8	150
Ahmadnagar (Mah)	579	MDB	54	67	47	CSH 1	15.3	123
Sangli (Mah)	625	SDB	35	30	56	CSH 1	26.6	159
Aurangabad (Mah)	726	SDB	25	41	21	CSH 1	9.1	156
Parbhani (Mah)	821	MDB	33	12	0	CSH 2	8.2	136
Bhir (Mah)	668	SDB	24	18	21	CSH 1	9.1	48
Satara (Mah)	803	SDB	34	51	15	CSH 1	20.4	156
Osmanabad (Mah)	810	MB	33	12	19	CSH 1	7.1	249
Buldhana (Mah)	803	SMB	33	36	1	CSH 1	12.7	318
Akola (Mah)	847	MB	29	16	0	CSH 1	12.1	319
Amaravati (Mah)	877	SMB	23	19	39	CSH 1	15.2	301
Nanded (Mah)	901	MDB	38	7	8	CSH 1	8.7	151
Wardha (Mah)	1090	MB	29	15	8	CSH 1	21.1	301
Nagpur (Mah)	1196	SMB	35	8	0	CSH 1	20.5	158
Mandsaur (MP)	592	MR/B	23	21	0	Vidisha	14.5	310
Belgaum (Kar)	785	MB	25	10	48	CSH 1	21.0	150
Bellary (Kar)	575	R	33	42	15	CSH 1	35.3	158
Shimoga (Kar)	1526	R/L	11	83	23	CSH 1	48.2	153
Shimoga[2] (Kar)	1526	R/L	na	97	100	CSH 1	48.2	121
Mysore (Kar)	762	R	18	46	25	CSH 1	21.4	139
Anantapur (AP)	544	MR/B	14	3	44	CSH 1	6.8	159
			B. Pearl millet districts					
Banaskanta (Guj)	627	D/GB	57	23	1	HB 3	5.0	313
Kaira (Guj)	815	GB	34	85	48	HB 3	49.4	320
Rajkot (Guj)	590	MR/B/A	22	80	51	HB 3	22.0	320
Hissar (Har)	515	A	21	54	98	HB 3	14.1	320
Rohtak (Har)	219	A	16	43	85	HB 3	10.8	317
Jaipur (Raj)	548	A	36	30	37	HB 1	4.4	311
Aurangabad (Mah)	726	SDB	13	45	1	HB 3	9.1	150

Continued

Appendix III continued.

District (State)	Normal annual rainfall (mm)	Major soil type	% of area under sorghum/ pearl millet	% of cropped area under HYV 1973-74	% of HYV area under irrigation 1973-74	Dominant HYV in 1973-74	Fertilizer consumption (kg/ha)[1]	Number of cultivators in the AAE sample
1	2	3	4	5	6	7	8	9
Parbhani (Mah)	821	MDB	1	14	0	HB 3	8.2	24
Bhir (Mah)	668	SDB	13	33	3	HB 1	9.1	112
Jalgaon (Mah)	741	MDB	13	72	4	HB 3	26.8	153
Ahmadnagar (Mah)	579	MDB	12	23	64	HB 3	15.3	158
Sangli (Mah)	625	SDB	3	5	100	HB 1	26.6	160
Sholapur (Mah)	584	MDB	2	7	86	HB 3	10.3	292
Morena (MP)	436	MB	19	22	2	HB 4	17.2	313
Guntur (AP)	832	R/DB	6	2	95	HB 1	59.7	151
Chittoor (AP)	823	R	5	65	100	HB 4	19.1	127
Nellore (AP)	952	R/L	6	94	100	HB 4	22.0	134
Bellary[2] (Kar)	575	R	6[3]	94	100	HB 4	35.3	138
Coimbatore (TN)	1030	MR/B	5	33	100	HB 4	53.8	115
Coimbatore[2] (TN)	1030	MR/B	na	40	99	HB 3	53.8	100
Madurai	855	MR/B	4	51	87	HB 3	36.4	160
Madurai[2]	855	MR/B	na	68	85	HB 3	36.4	159
Tirunelveli	815	MR/B	11	22	95	HB 3	31.4	120
Tirunelveli[2]	815	MR/B	na	10	34	HB 3	31.4	99
Chingleput	1211	R/L	1	70	100	HB 4	74.4	76
Chingleput[2]	1211	R/L	na	45	70	HB 1	74.4	62

Source: Raheja et al. 1976. Data in column 1 and 2 taken from their 1970-71 report.

[1] Data pertain to 1975-77.

[2] Postrainy-season crop (rainy+postrainy).

[3] Total pearl millet (rainy+postrainy).

MB=medium black; MDB=medium-deep black; SDB=shallow-deep black; SMB=shallow-medium black; MR/B=mixed red and black; R=red; L=laterite; D/GB=desert gray-brown; R/DB=red deep black; and A=alluvial.

Appendix IV. Actual rates of application of fertilizer nutrients (kg/ha fertilized) and extent of cropped areas fertilized for HYV of sorghum and pearl millet in selected districts.

	Rate per fertilized ha (HYV)			% of area fertilized (HYV)		
District (State)	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha	N %	P_2O_5 %	K_2O %
	A. Sorghum districts					
Jalgaon (Mah)	40	27	12	78	63	18
Ahmadnagar (Mah)	72	29	0	53	24	0
Sangli (Mah)	60	25	15	39	19	15
Aurangabad (Mah)	55	27	12	24	15	7
Parbhani (Mah)	47	19	18	43	25	25
Bhir (Mah)	23	19	21	24	41	25
Satara (Mah)	59	27	13	64	26	22
Osmanabad (Mah)	29	21	16	38	32	32
Buldhana (Mah)	33	33	18	88	88	56
Akola (Mah)	48	27	17	52	42	21
Amaravati (Mah)	42	29	22	90	72	56
Nanded (Mah)	31	15	4	47	28	14
Wardha (Mah)	44	18	15	60	43	34
Nagpur (Mah)	35	27	16	81	79	58
Mandsaur (MP)	63	24	29	81	71	54
Belgaum (Kar)	94	27	24	93	60	56
Bellary (Kar)	13	11	11	72	72	70
Shimoga (Kar)	38	24	23	90	89	85
Mysore (Kar)	49	36	32	31	17	17
Anantapur (AP)	47	0	0	24	0	0
Shimoga[2] (Kar)	57	35	33	97	95	74
	B. Pearl millet districts					
Banaskanta[2] (Guj)	50	0	0	23	0	0
Kaira[2] (Guj)	36	42	0	75	12	0
Rajkot[2] (Guj)	30	32	0	77	51	0
Hissar[2] (Har)	46	61	0	65	3	0
Rohtak[2] (Har)	46	0	0	84	0	0
Jaipur[2] (Raj)	36	17	0	70	18	0
Jalgaon[2] (Mah)	32	21	8	74	54	20
Ahmadnagar[2] (Mah)	64	37	28	84	28	8
Sangli (Mah)	60	0	0	47	0	0
Aurangabad[2] (Mah)	29	19	18	36	29	16
Parbhani (Mah)	27	12	12	29	16	16
Bhir[1] (Mah)	24	18	16	22	21	21
Sholapur (Mah)	28	0	0	27	0	0
Morena[2] (MP)	53	38	0	95	81	0
Guntur (AP)	56	28	16	62	48	45
Chittoor (AP)	75	34	33	98	54	46
Nellore (AP)	41	22	18	91	67	41
Coimbatore (TN)	99	42	33	90	74	66
Madurai (TN)	35	18	18	74	57	57

Continued.

Appendix IV continued.

District (State)	Rate per fertilized ha (HYV) N kg/ha	P_2O_5 kg/ha	K_2O kg/ha	% of area fertilized (HYV) N %	P_2O_5 %	K_2O %
Tirunelveli[2] <TN)	74	28	28	80	40	40
Chingleput (TN)	44	31	27	91	75	71
Coimbatore[1] (TN)	52	31	30	86	56	56
Madurai[1] (TN)	18	6	6	78	42	42
Tirunelveli[1,2] (TN)	26	0	0	40	0	0
Chingleput[1] (TN)	48	26	24	86	63	57
Bellary[1] (Kar)	64	30	26	98	83	79

Source: Raheja et al. 1976.

1. Postrainy-season crop.
2. Traditionally important pearl millet producing districts.

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