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Farmer's Fertilizer Practices in the Semi-Arid Tropics of India

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Abstract

This paper describes the fertilizer and farm yard manure practices in the farmers' fields in seven villages located in five contrasting agroclimatic zones of India's Semi-Arid Tropics (SAT) over a period of three cropping years (1982/83 to 1984/85). The results indicate that in these rainfed areas of India's SAT a large proportion of cropped land still does not recieve any nutrients either from farm yard manure and/or fertilizer. The fertilizer use is mostly confined to irrigated land. Despite heavy investment for irrigation all the irrigated land do not receive fertilizer. Application of farm yard manure (FYM) is common in dry land and is mostly used as a soil-improvement strategy rather than nutrient enhancing strategy. FYM is more a complement than substitute to fertilizer and has residual effect for 2 to 3 seasons.

Most of the fertilizer is applied used to high value cash crops planted as improved cultivars. There are sharp differenoes in the use of fertilizer across villages. In general rabi (postrainy season) crops are starved of nutrients application especially in those regions where postrainy season cropping on residual soil moisture is prevalent. In these regions adoption of improved cultivars and acceess to irrigation is limited. Due to poor response of fertilizer on crop yields also use of fertilizers is quite low in these areas.

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FARMER'S FERTILIZER PRACTICES IN THE SEMI-ARID TROPICS OF INDIA

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Gunwant M. Desai

Chemical fertilizers and farm yard manure (FYM) are the two main sources of plant nutrients applied by farmers in India's semi- arid tropics (SAT). The most common chemical fertilizers used in the study villages are urea, diamonium phosphate, and some important complex fertilizers. Occasionally, farmers spread tank silt or pen sheep on their fields. But these soils ammendments are localised and limited to a few of the crops such as paddy, wheat, and castor/or cotton.

In this paper, we analyze the pattern of fertilizer use at the farm and plot levels. The analysis is based on detailed data collected under Village Level Studies Level Studies program (VLS) of Economics Group of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). This is a most comprehensive data set collectded by resident investigators from about 200 farmers in seven villages in five contrasting agroclimatic regions of India's SAT.

The analysis is organized into five sections: A brief description of the study villages are given in the first section. The second section provides information about the variation in mean levels of nutrients' application across farmers and agroclimatic regions. Interactions between the application of farm yard manure and fertilizer are analysed in the third section. Correlates, such as irrigation, cropping season, cropping systems, local and high yielding

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cultivars, and farm size, with fertilizer use are discussed in the fourth section. The determinants of the farm use of chemical fertilizer and FYM are analysed in the fifth section.

DATA

For the analysis, the panel data collected by ICRISAT from about 210 farmers representing small, medium, and large farm size group in five contrasting agroclimatic zones of India's SAT have been used. Looking to the richness of data, which contains detailed information of same plot cropped by the farmers for a period of 5 to 10 years and other socio-economic characteristics of the farmers, it would be most suited to examine the above mentioned issues from micro-level perspective. The details of the methodology of data collection and description of information collected are given in Singh et al (1985)

REGIONAL PROFILE

The studied villages are located in five districts namely Mahbubnagar, Sholapur, Akola, Sabarkantha and Raisen representing different agroclimatic regions in the semi-arid tropics of India and represent different climate, soil and cropping patterns. The location and important characteristics of studied villages are given in Figure 1 and Appendix 1. The annual rainfall varies from 500 mm to more than 1200 mm and is highly erratic in these study regions. The soils are sandy alfisol with poor moisture retention capacity to deep vertisol with higher moisture retention capacity. Major crops planted in these regions are sorghum, pearl millet, castor, cotton, groundnut, wheat, chickpea, pigeonpea, and soybeans. However, all these crops are not planted in every region. During last five to ten years some of these villages have experienced technical change but still some of them have not been able to keep pace with others. A brief description of selected village in each district is described in the following paragraphs.

Mahbubnagar District (Andhra Pradesh State) is endowed with medium to shallow alfisols (red

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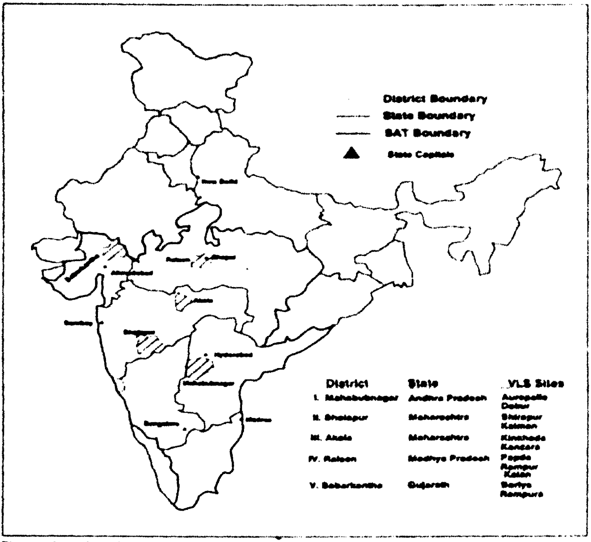

Figure1. Location of study villages in India's SAT.

soils) with low moisture retention capacity. Annual rainfall is low and erratically distributed both within and across years. Irrigation, specially from tanks and wells, is relatively high in this region. One of the two villages in this district has more irrigated and HYV paddy and groundnut are planted in most of the irrigated fields. The other village in this region has relatively low irrigation and castor, sorghum intercropped with pearl millet and pigeonpea are the important dryland crop.

Sholapur District (Maharashtra State) belongs to the drought prone region of the state. The rainfall is quite low and highly erratic across years and within seasons. Rain is received in two phases during the monsoon season. The soil in this region is medium to deep black with high moisture retention capacity. Irrigation is limited and based on undependable recharge of the groundwater. Postrainy season sorghum is the main cropping system is this region but nitrogen use to sorghum is negligible because response is poor when sorghum is planted after the end of monsoon, as is traditional. Advancing the planting date increases the risk (Dovark 1987). Farmers plant sorghum (local improved) in the post rainy season year after year in the same field. Because of sticky nature of soils crops are not planted in the monsoon season. Use of nutrients is very low except in case of a few crops like sugarcane and vegetables. However, the area under these crops is negligible. During rainy season, a few of the important crops such as pigeonpea, minor pulses are planted in limited area on shallow soils.

Crop yields are very low, and probability of crop failure is quite high (Singh & Walker, 1984). Recently, sunflower has been adopted by the farmers which is relatively a remunerative crop. This region has the benefit of Employment Guarantee Scheme during slack seasons and most of the households, except a few large farmers belonging to higher caste actively participate in the labor market. Most farmers lack adequate production assets like bullocks and implements, etc.

Akola district (Maharashtra State) is characterized by medium but stable rainfall with medium black cotton soils. The irrigation is negligible and cotton is planted by most of the farmers. Some of the farmers plant high yielding/hybrid sorghum in the monsoon season.

Wheat, groundnut, and chickpea are planted in the post monsoon season mainly in the irrigated fields. Cotton is mostly planted as an intercrop with sorghum and pigeonpea. Mungbean is widely planted in the intercrop sorghum as a short duration crop and is quite profitable. Farmers are progressive and use relatively more fertilizer in the dryland and plant high yielding varieties of sorghum and cotton. This region has also advantage of Employment Guarantee and Food for Work program during slack season. In the later years of enquiry, post-rainy season cropping experienced a substantial change due to increased access to canal water.

Sabarkantha District (Gujarat State) has sandy soil and low rainfall. Irrigation is quite high and most of the farmers plant hybrid pearl millet, castor and groundnut. Intercropping is a common practice in the dryland. A few of the farmers plant flannel ('saunf') as a high value crop. In one of the two villages (Rampura) the social set up is different and is dominated by enterprising 'Patel' community whereas in the second village (Boriya) 'Thakurdas' belonging to higher caste who are not very enterprising and do not take enough interest in farming. The first village has higher irrigation compared to the second one and plant more high value crops in irrigated fields. These villages are well connected with road and get regular employment from the small scale industries in the nearby town.

Raisen District (Madhya Pradesh) has high rainfall and deep black soils. Irrigation is negligible and farmers plant crops in the post monsoon season on residual soil moisture. Wheat and chickpea are the important post monsoon crops planted on dry land and in most of the villages fertilizer use is not common. During monsoon season farmers plant pigeonpea and soybean. Pigeonpea yields are quite uncertain due to cold climate and frost problem.

The land is more unevenly distributed and some of the holdings are quite large. A few of the farmers own tractors while most of the farmers do not even own bullocks. They also use tractors on custom hiring. The overall economic condition is poor in both the villages but in Rampura Kalan, the farmers are relatively more educated and progressive than in Papda

LEVELS OF APPLICATION

Farm Level

On average, one farmer in five did not use fertilizer or FYM in the study period (1982-84). The majority of farmers (53%) applied both manure and fertilizer at least once during the three years (Table 1)

On average, farmers applied 23 kg of total nutrients (N+P+K) per ha of cropped area from both FYM and fertilizer. Fertilizer supplied was about two-thirds of the total nutrients. The pattern of nutrients' application varied to a large extent (3 to 43 kg/ha of cropped area) across regions and farmers. The mean levels of nutrients' application was negligible in a few of the villages whereas in other villages farmers applied up to 43 kg of NPK per ha of cropped area. The level of NPK application per ha was positively skewed (Table 2) Many farmers applied very low doses of nutrients; a few applied relatively heavy doses (Appendix 3).

There were sharp differences in the use of fertilizer across villages and farmers To examine the relative importance of these differences the variation in application levels was partitioned into the following sources with analysis of variance techniques: (1) village; (2) year; (3) inter-households; and (4) others Differences in village accounted for about 28% variataion in the level of nutrients application. Year to year fluctuations accounted for only 2% of the total variation. Much of the variation (43%) in the level of nutrients application was observed because of inter-household differences within the village. The remaining 24% of the variation in the level of nutirents' application was attributed to other factors. Therfore, inter-household variation within a villages and inter-village variation were both important contributors to the total variation in NPK use per ha of cropped area.

Plot Level

On average more than half (58%) of the cropped area did not receive any nutrients either from FYM and/or fertilizer in these seven villages of India's semi-arid tropics during the early 1980s. The average percent of cropped area not receiving any nutrients varied by village from

Table 1. Mean and ranges of levels of fertilizer and FYM use in the seven study villages of India's SAT, 1982-84.

Particular	Mean	Range [1]
Total Number of farmers	206	
% of farmers applying:		
Nothing	19	7-36
Only FYM	22	0-68
Only Fertilizer	7	0-18
Both FYM and fertilizer	53	8-83
Level of NPK [2] (kg/ha of cropped area) from:		
FYM	8	2-23
Fertilizer	15	0-28
Total	23	3-43

[1]indicates the ranges of mean application levels across the seven study villages.
[2] Total NPK from FYM was estimated as 1% (0.5% n, 0.3% P, and 0.2% K).

Table 2. Number of farmers using different level of nutrients (NPK in kg/ha of cropped area) in seven study villages of India's SAT, 1982-84.

Level of fertilizer and FYM use (total NPK Kg/ha of	Number of farmers cropped area)	% of total farmers	Cumulative % of farmers
Nil	37	18.0	18.0
Less than 10	52	25.1	43.1
11- 20	23	11.2	54.3
21- 30	35	17.0	71.3
31- 40	10	4.9	76.2
41- 50	5	2.4	78.6
51- 60	17	8.3	86.9
61- 70	11	5.3	92.2
71- 80	9	4.4	96.6
More than 80	7	3.4	100.0
Total	206	100.0	

31 to 89%. The variation in the pattern of nutrients application across villages was mainly attributed to sharp differences in the cropping systems, types of crops (cash/food crops), access to irrigation, rainfall distribution, and cropping season.

In general, a large number of fields received only fertilizer compared to only FYM. About 19% of the cropped land received both FYM and fertilizer. Application of FYM was more common in the dry land villages; fertilizer use was concentrated in the relatively more irrigated villages.

The application of nutrients was heavily biased in favor of nitrogen (N) as it alone accounted for more than 53 to 97% of the total nutrients applied to crops by villages (Figure 2). Application of phosphorous (P_2O_5) and potash (K_2O) was limited, except in some of the villages where most of the farmers applied mainly FYM (Papda and Rampur Kalan). Higher use of phosphorous in Aurepalle was mainly because of paddy, which received most of the nutrients from both as basal and top dressing. In Shirapur, mainly nitrogenous fertilizers, were used to top dress irrigated crops. Wherever irrigation was limited, fertilizer application was heavily biased towards nitrogen basal doses were not common

The mean application of total nutrients (NPK) per ha of cropped area was 27 kg varying from the range of 4 to 49 kg across the seven villages (Table 3). Mean levels of nutrients was relatively low (37 kg/ha of cropped area) in those plots which mainly relied on FYM as the main source of nutrients application compared to those fields which received fertilizer alone (49 kg/ha) or both fertilizer and FYM (116 kg/ha).

FYM contributed about 33% to the total nutrients application in these villages (Table 3). But in a few of the villages most of the cropped land relied on FYM as the main source of nutrients. The contribution of FYM was as high as 97% in some of the villages like Papda and Rampur Kalan with limited sources of irrigation (Appendix 4)

The application of total nutrients was quite low especially in those villages where irrigation was negligible and crops were planted during postrainy season on residual soil moisture. These villages heavily relied on FYM for nutrients application. The application of

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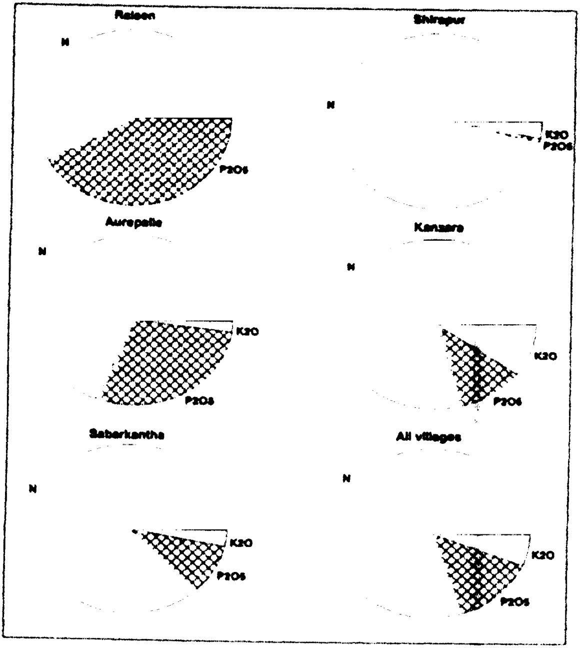

Figure 2. Percentage share of N, P2O5, and K2O in total nutrients use in the villages, 1982-84

Table 3. Proportion of plots receiving fertilizer and farm yard manure, and mean level of nutrients use in seven villages of India's SAT, 1982-84.

Particular	Mean	Range [1]
Proportion of cropped area receiving (%):		
No nutrients	58	31-89
Only FYM	10	3-25
Only fertilizer	25	1-49
Both FYM and Fertilizer	7	0-19
Share (%) of FYM in total NPK use	33	23-97
Share (%) of different nutrients in use of total NPK:		
N	81	53-97
P	14	1-47
K	5	0-10
Mean application level of total NPK (kg/ha) of:		
Only manured area	37	11-80
Only fertilized area	49	22-79
Both manured and fertilized	116	31-144
All	27	4-49
Mean level of NPK from FYM (Kg/ha) in :		
1982/83	9	3-28
1983/84	10	4-20
1984/85	10	4-23
Mean level of NPK from fertilizer (Kg/ha) in :		
1982/83	16	0-29
1983/84	22	1-41
1984/85	22	0-47

[1]indicates ranges of mean application levels across seven villages.

chemical fertilizers was negligible mainly because of poor response of fertilizer in low moisture conditions.

The level of fertilizer is also influenced by use of nutrients in the previuos years. It was expected that farmer apply less fertilizer in those plots where FYM was applied in the previous season/cropping year. Farmers perceive that use of FYM has residual effects for two to three years. In addition to this crop rotation practice followed by the farmers also affect the fertilizer use. The residual effect of FYM influencing the fertilzer use was tested with simple OLS regression using plot level information in seven villages. The results clearly indicate that application of FYM in the previous season significantly reduces the use of fertilizer doses in the current season.

The distribution of plots which received fertilizer and FYM indicates that basal doses of fertilizer was not common in many villages But in most of the fertilized plots fertilizer was applied at the time of sowing (Table 4 and Figure 3). But basal application of fertilizer varied across crop and regions. For some of the crops such as paddy and cotton fertilizer was used in instalments after sowing. The FYM is normally applied before sowing. In most of the manured plots FYM was applied 2 to 3 months before sowing but there were few plots where it was applied even more than 6 months before sowing (Table 5).

It is expected that the low levels of fertilizer use are usually in N (Nitrogen) while higher levels of use are in other nutrients for those farmers who used fertilizers. In otherwords, one would expect that the share of nitrogen in total nutrients application from fertilizer would decline with the increase in the level of fertilizer use. This hypotheses was tested by ploting the share of N in use of total NPK against the mean level of total fertilizer use both at micro-level and macro-level using plot and district level information on fertilizer use The micro-level evidences clearly indicate that those farmers who used low level of fertilizer applied mainly nitrogen whereas other farmers who used higher doses of fertilizer used other nutrients also (Figure 4).

Table 4. Distribution (%) of fertilized plots according to date of sowing in four study villages of India's SAT, 1982-84

Weeks Before sowing	Village				Total	% to total
	Aurepalle	Kanzara	Boriya	Rampura		
	----------- Number of plots -----------					
Weeks before sowing						
> 4	4	0	2	2	8	0.5
4	2	0	0	0	2	0.1
3	1	0	1	0	2	0.1
2	1	0	0	3	4	0.3
1	46	21	52	68	187	12.2
Sowing time	60	41	70	223	394	25.7
Weeks after sowing						
1	43	49	67	104	163	10.6
2	27	41	34	87	189	12.3
3	19	28	22	48	117	7.6
4	9	21	39	38	107	7.0
5	1	27	16	26	70	4.6
6	0	20	15	24	59	3.9
7	1	19	3	14	37	2.4
8	0	11	6	12	29	1.9
>8	10	22	10	29	71	4.1
Total	216	300	337	678	1531	100.0

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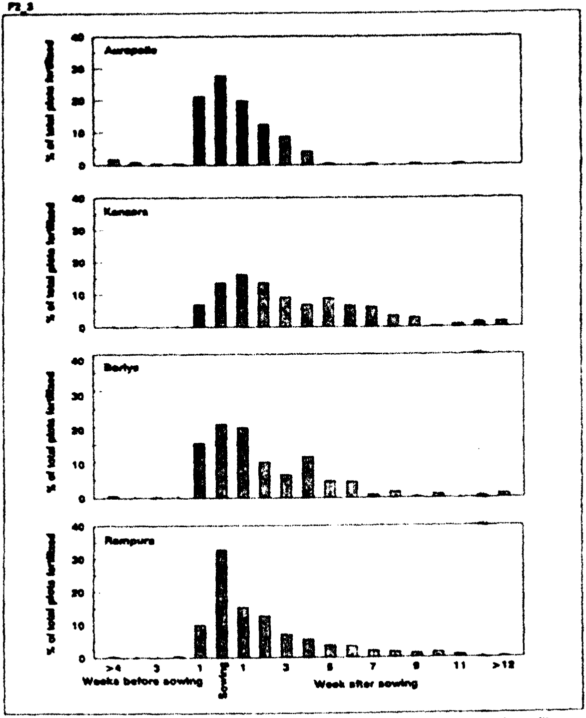

Figure 3. Percentage distribution of fertilized plots according to sowing date in four villages of India's SAT, 1982-84

Table 5. Distribution (%) of manured plots according to date of sowing in seven study villages of India's SAT, 1982-84.

Week	Aurepalle	Shirapur	Kanzara	Boriya	Rampura	Papda	Rampur Kalan	Total	% to total
	Village								
	------------ Number of plots ------------								
Sowing time	0	3	8	50	3	0	0	64	8.1
Months before sowing									
One	39	24	68	152	8	2	5	298	37.7
Two	47	35	7	29	6	16	23	163	20.6
Three	32	15	3	6	6	7	3	72	8.8
Four	14	13	0	7	15	0	1	50	6.3
Five	12	7	0	0	12	1	0	32	4.0
Six	7	1	0	0	7	38	15	68	8.6
Seven	3	0	0	0	2	7	9	21	2.7
Eight	13	0	0	0	9	0	1	23	2.9
Total	167	98	86	244	68	71	57	791	100.0

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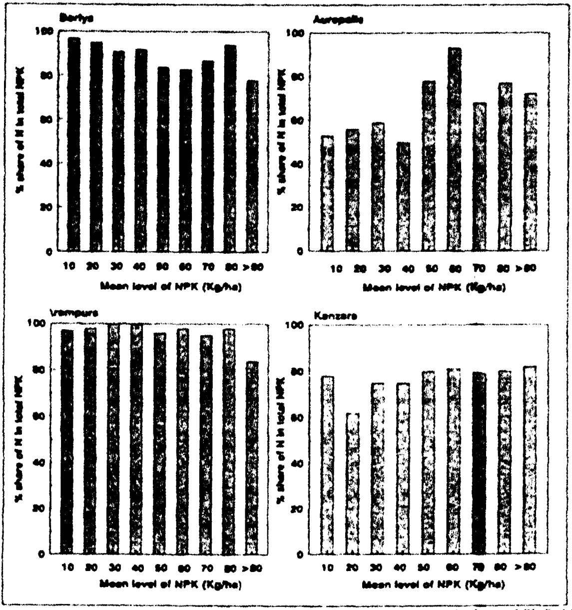

Figure 4. Percentage share of nitrogen in use of different level of total nutrients used (Kg/ha) in four villages of India's SAT, 1982-84.

FERTILIZER AND FYM INTERACTIONS

Are FYM and fertilizer complements or substitutes in crop production in India's SAT ? Nowadays, fertilizer availability is than supply of farmyard manure which depends on livestock supply which is constrained by fodder availability. Farmers perceive that application of FYM is helpful in affecting physical properties of the soil making fields easier to cultivate. Farmers also believe that FYM provides more organic matter to their fields with residual productivity effects over time (Motavalli 1991). Therfore, from the farmers' percepective fertilizer and FYM would appear to be complements rather than substitutes.

The question of complementarity was examined by comparing the probabilities of manured or fertilized plots with those plots receiving both manure and fertilizer. Multiplying the empirical probabilities of manured plots with the probabilities of fertilized plots gives a joint probability which is compared with the empirical joint probability of a plot receiving both FYM and fertilizer. If FYM and chemical fertilizer were complements, the empirical probability of the two events occuring together should be greater than the multiplied probability of each event seperately. Equal probability indicate independence. Higher probabilities in column (3) than in column (4) in Table 6 are consistent with substitutability view of FYM and chemical fertilizer. Except for Rampura Kalan where use was negligible, the empirical joint probabilities greatly exceeded the prduct of their independent use. This difference supports the view that FYM and chemical fertilizers are complements in production.

The relationship between the application of manure and fertilizer in those plots where both were applied also supports the notion that FYM and fertilizer are not viewed as substitutes. A scatter diagram of mean per ha nutrients (NPK) application from FYM and fertilizer in those fields, where both manure and fertilizer were used, suggests the absence of a definitive relationship in dry and wet plots (Figure 5). Statistically insignificant correlation coefficients of -0.066 for dry plots and 0.102 for wet plots indicate that levels of application of both sources of nutrients are independent when they are applied together.

Table 6. Probability of plots receiving farm yard manure, fertilizer, and both (manure and fertilizer) in seven study villages of India's SAT, 1982-84.

Village	Probability of plots			
	Manured	Fertilized	Manured X Fertilized	Both (manured and fertilized)
	1	2	3	4
Aurepalle	0.12	0.27	0.0324	0.15
Shirapur	0.06	0.04	0.0024	0.01
Kanzara	0.03	0.47	0.0141	0.19
Boriya	0.02	0.49	0.0098	0.05
Rampura	0.04	0.48	0.0192	0.08
Papda	0.25	0.01	0.0025	0.02
Rampur Kalan	0.22	0.01	0.0022	0.00
All villages	0.10	0.25	0.0250	0.08

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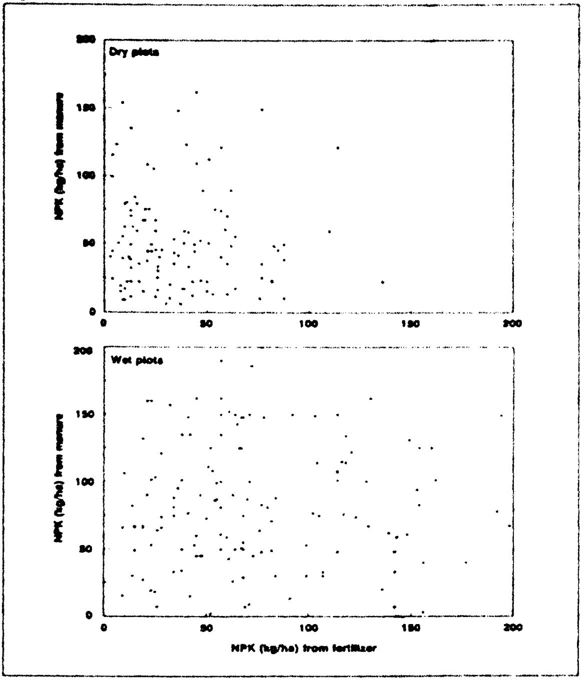

Figure 5. Joint application of NPK (Kg/ha) from FYM and fertilizer in dry and wet fields in seven villages of India's SAT, 1982-84.

CORRELATES OF NUTRIENTS' APPLICATION

It is clear from foregoing discussion that there are a number of factors associated with the application of FYM and/or fertilizer. These include the extent and distribution of rainfall especially during cropping season and onset of monsoon, farm size, extent of intercropping, post-monsoon cropping, adoption of high yielding/hybrid cultivars, types of crops planted (cash and food crops), output prices, yield responsiveness of fertiliser to crops, availability of fertilizers, availability of farm yard manure, and the prices of fertilizer, etc. We examine the possible association of fertilizer use with some of these factors in the following paragraphs.

Irrigation

Nutrients' application specially fertilizer use is often thought to be positively associated with access to irrigation. In the seven study villages, more than half (53%) of the farmers had no access to irrigation. Most of those who had access to irrigation were not able to provide full irrigation to all of their fields. Only about 20% of the farmers had access to irrigation in more than 40% of their fields (Table 7 and Appendix 5).

The application of fertilizer and FYM vary to a large extent across farmers having access to irrigation and those who do not have irrigation. Most (83%) of the farmers having access to irrigation applied both FYM and fertilizer to their crops compared to those who had no irrigation facilities (26%). In contrast, many farmers (37%) with no irrigation facilities applied only FYM compared to merely 6% of the farmers with irrigation.

About 96 out of 206 sample farmers had access to irrigated farmers in the study villages and accounted for about 62% of the total cropped area and used most of the FYM (70%) and fertilizer (92%) (Table 8). The farmers with no irrigation relied heavily on FYM as 64% of the total nutrients applied to their crops was received from that source.

The mean level of nutrients application by these two groups of farmers was also quite different. On average, farmers with irrigation facilities applieed 3.4 times higher nutrients (31 kg of total NPK/ha of cropped area) than those who had no access to irrigation (9 kg/ha).

Table 7. Number of farmers having access to irrigation in seven study villages of India's SAT, 1982-84.

Level of irrigation (% of total cropped area)	Number of farmers	% of total farmers
Nil	110	53.4
Less than 10	14	6.8
11- 20	10	4.9
21- 30	15	7.3
31- 40	15	7.3
41- 60	37	18.0
More than 60	5	2.3
Total	206	100.0

Table 8. Proportion of farmers applying farm yard manure (FYM) and fertilizer, proportion of cropped area FYM and fertilizer, and level of nutrients application (kg/ha of cropped area) by farmers with and without irrigation in seven study villages of India's SAT, 1982-84.

Particular	Farmers with	
	No irrigation	Irrigation
Total Number of farmers	110	96
% share of total farmers	53	47
% share in total cropped area	38	62
% share of total total FYM	30	70
% share of total fertilizer	8	92
% share of FYM in total nutrients	64	28
% of farmers applying:		
Nothing	31	4
Only FYM	37	6
Only Fertilizer	6	7
Both FYM and fertilizer	26	83
Level of NPK (kg/ha of cropped area) from:		
FYM	6	9
	(2-23)	(2-22)
Fertilizer	3	22
	(0-23)	(0-32)
Total	9	31
	(2-30)	(4-53)

(Figures in parentheses are ranges of mean application levels across the seven villages).

Fertilizer application is heavily skewed to irrigated fields. It is evident from Table 9 that most of the fertilizer (66%) was applied to irrigated fields compared to unirrigated fields (Appendix 6). In contrast FYM was mostly used in unirrigated fields. This pattern is consistent with farmer's perception of farm yard manure as a soil-ameliorating rather than a soil-fertility enhancing strategy. The differences in the application rates of FYM (either alone or in combination with fertilizer) between unirrigated and irrigated fields were not as marked as for fertilizer (Figure 6).

Nonetheless, fertilizer application was not limited to the irrigated fields. About 22% of the unirrigated fields also received fertilizer whereas 18% of the irrigated fields did not receive any fertilizer. Inspite of the heavy investment in irrigation, farmers did not apply fertilizer to all the irrigated fields.

What was the crop composition of the irrigated fields that were not fertilized ? One would expect a dominance of local cultivars of coarse cereals and low value crops. But even some of the improved cultivars of superior cereals, such as paddy and wheat, as well as high value crops like castor, cotton, sugarcane, and vegetables did not receive any nutrients though they were irrigated (Table 10). These results hints at the considerable scope for the expansion of fertilizer use on the irrigated land within these predominantly dryland production villages.

The cumulative distributions in Figure 7 displayed considerable regional variation in the intensity of fertilizer and FYM application rates. The gap in use intensity between irrigated and dryland fields is highest in drought-prone Aurepalle with shallow red soils. The disparity narrows in rainfall assured Kanzara with medium-deep black soils. Figure 5 also shows that the vast majority of fields in Shirapur were starved for fertilizer. Sixty percent of irrigated plots were not fertilized

Season

Application of nutrients is limited in postrainy season compared to the rainy season. The summer season is normally irrigated; therefore, application of nutrients is also quite high. Both FYM and fertilizer are applied in larger areas in rainy season than in postrainy season

Table 9. Share of cropped area, farm yard manure, and fertilizer in unirrigated and irrigated fields, and mean level of total NPK (kg/ha of cropped area) use in seven study villages of India's SAT, 1982-84.

Particular	Unirrigated		Irrigated	
Share in cropped area (%)	82	(56-99)	18	(1-44)
Share in use of total FYM (%)	66	(28-100)	34	(0-72)
Share in total use of fertilizer (%)	35	(0-100)	65	(0-100)
Share of FYM in total use of nutrients (%)	49	(27-100)	21	(0-100)
Proportion of cropped area:				
Manured (%)	17	(6-28)	17	(0-27)
Fertilized (%)	22	(0-62)	82	(0-92)
Mean dose of total NPK (kg/ha of cropped area) from				
FYM	6	(2-16)	14	(0-21)
Fertilizer	6	(0-26)	53	(0-76)
Total	12	(2-37)	49	(2-94)

Figures in parenthese are ranges of mean application levels across the seven villages.

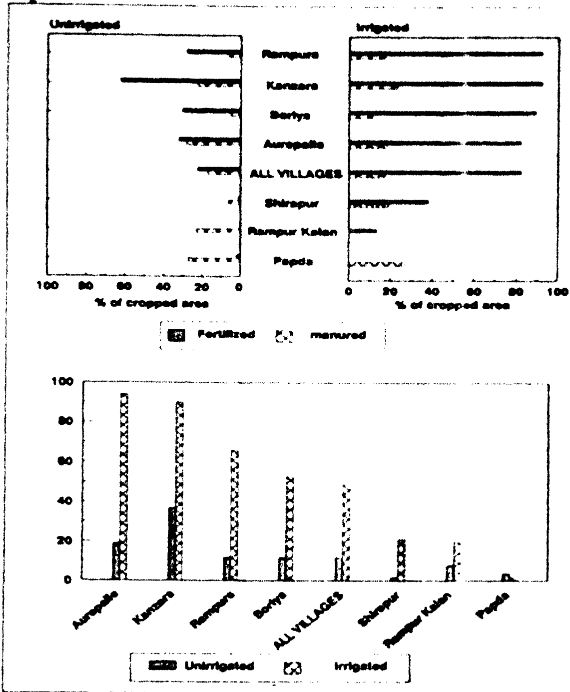

Figure 6. Percentage of unirrigated and irrigated area fertilized and manured, and mean level of total NPK (kg/ha of cropped area), 1982-84

Table 10. Share (%) of important crops in total irrigated receiving no nutrients in seven study villages of India's SAT, 1982-84.

Crops	% share of total irrigated area receiving no nutrients	
Cereals		48.6
Sorghum local	17.6	
Sorghum HYV	3.4	
Wheat local	11.8	
Wheat HYV	2.9	
Paddy local	2.6	
Paddy HYV	3.1	
Maize	3.8	
Pearl millet	3.4	
Oilseeds		17.4
Groundnut	6.8	
Castor local	4.7	
Castor HYV	4.2	
Cotton	1.7	
Pulses		7.1
Chickpea	3.8	
Minor pulses	3.3	
Vegetables		9.8
Sugarcane		4.8
Fodder		5.2
Other crops		6.4

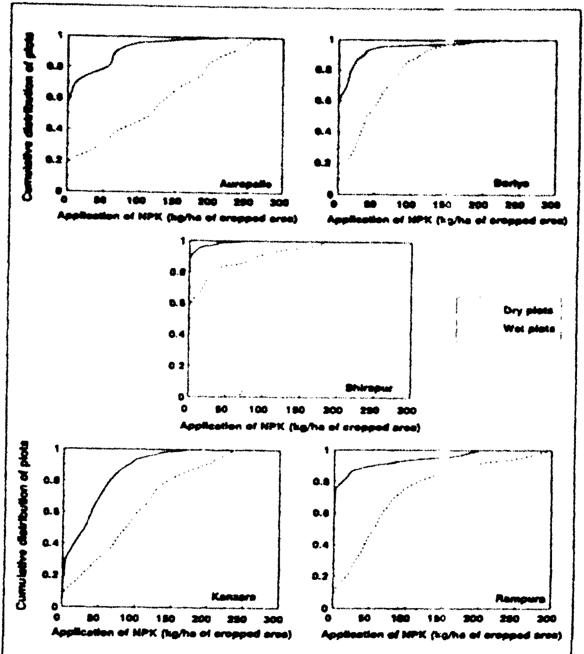

Figure 7. Cumulative distribution of dry and wet plots using total NPK (kg/ha of cropped area) from both fertilizer and farm yard manure, 1982-84.

(Table 11 Apppendix 7). However, in kharif- fallowing areas (Papda, Rampur kalan, and Shirapur) its use was negligible in unirrigated fields in both the seasons.

In general, the postrainy season is starved for nutrients. Table 11 shows that about 83% of the FYM and 94% of the fertilizers were used in rainy season though they accounted for only 58% of the total cropped area.

High Yielding Varieties

In the study villages, adoption of high yielding/hybrid (HYV) cultivars was limited in early 1980s. On average, about 77% of the cropped area was planted with local cultivars. In some of the villages (Shirapur, Papda, and Rampur Kalan) almost all the cropped area was sown to local cultivars only. The modern cultivars of a few crops such as paddy, wheat, sorghum, castor, cotton, and pearl millet are planted in some of the villages. The proportion of cropped area planted with modern/improved cultivars was negligible in most of the dry villages where kharif fallowing was prevalent.

On average, about 48% of the fields planted with HYVs received irrigation compared to 9% of the local cultivars. Most of the cropped area planted with local cultivars did not receive irrigation. But in a few of the villages even modern cultivars also did not receive irrigation. Most (76%) of the fields planted with modern cultivars (HYV's) received fertilizer compared to local cultivars (19%). It is evident from Table 12 and Figure 8 that the difference in the proportion of cropped area receiving FYM was not marked (Figure 8). The higher proportion of cropped area receiving fertilizer is again mainly due to the fact that a larger proportion (48%) of HYVs receive irrigation compared to local ones (9%). However, it is also clear from Table 12 that in most of the villages a large proportion of HYVs were planted in unirrigated fields and did receive fertilizer (Appendix 8).

Most of the fertilizer (69%) is applied to HYV's compared to local varieties (31%). But the share of HYVs in total consumption of FYM was smaller (44%) than the locals (56%). Apparently HYVs get preference for fertilizer use compared to locals. This observation is furhter supported by comparing the mean doses of total nutrients per ha of cropped area. On

Table 11. Percentage of cropped area manured and fertilized, and mean level of total NPK (kg/ha of treated area) use by season in seven study villages of India's SAT, 1982-84.

Particulars	Kharif		Rabi		Summer	
	Unirri-gated	Irri-gated	Unirri-gated	Irri-gated	Unirri-gated	Irri-gated
Share in total cropped area (%)	48	7	34	6	a	4
Share in use of total FYM (%)	58	19	11	2	a	10
Share in use of total fertilizer (%)	34	24	2	24	a	15
Proportion of total cropped area (%):						
Manured	19	28	16	5	50	9
Fertilized	34	81	4	76	50	12
Mean level of total NPK (Kg/ha of cropped area) from						
FYM	8	19	3	2	70	16
Fertilizer	9	46	1	52	28	49
Total	17	65	4	54	98	65

a: indicates less than 1% share.

F2_8

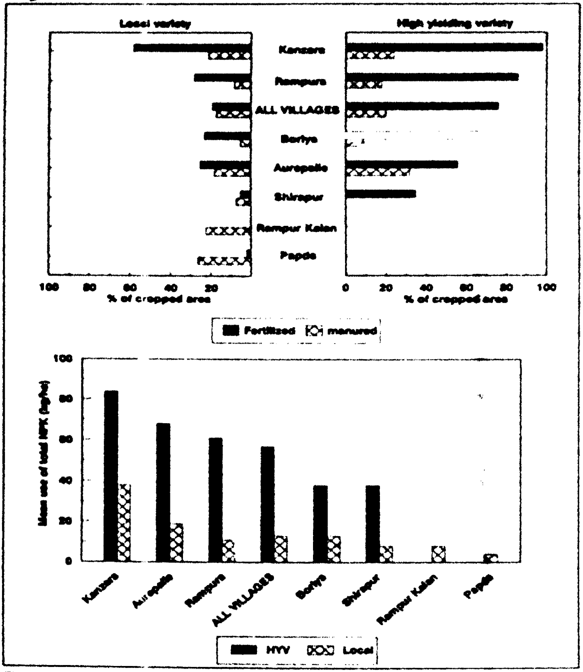

Figure 8. Percentage of local and HYV cropped area fertilized and manured, and mean level of total NPK use (kg/ha of cropped area), 1982-84.

average, HYVs receive about 57 kg of total nutrients (NPK) per ha of cropped area compared to local ones (13 kg). But there were sharp differences in the mean application of FYM and fertilizer per unit of cropped land across villages specially in case of HYVs than local cultivars (Table 12 and Appendix 9).

High Value Crops

Fertilizer consumption is also greatly influenced by the types of crops planted. It is clear from the pie charts (Figure 9) that (1) cereals accounting for about half of the total cropped area consumed a larger (60%) proportion of chemical fertilizer but smaller proportion of (31%) of FYM; (2) Oilseeds accounted for a higher proportion in the consumption of both FYM and fertilizer than their share in total cropped area and (3) pulses, which are seldom irrigated, rarely were fertilized or manured. Both castor and other crops, mainly fruits, vegetables and sugarcane, claimed a disproportionate share of FYM. In general, the distribution of FYM across the crops was more equitable than the distribution of chemical fertilizers which was heavily skewed towards cotton and cereals. The differences between the shares in area and fertilizer and FYM use supports the notion that farmers perceive differential advantages in applying more fertilizer or FYM to some crops than others

Intercropping

Planting more than one crop either by mixing seeds of other crops or planting in a row is a common practice of farmers in these dryland areas of India. Indeed, about 50% of the cropped area in the study villages in the early 1980s was intercropped (Table 13). Based on more than 4000 plots intercropped in seven villages in different regions of India' SAT in the 3-year study period, nearly half of the intercropped plots had at least one legume. This proportion varies from 28 to 78% across villages (Appendix 9).

Intercropping is considered as a strategy of dryland farmers, but it is practiced even in about 10% of irrigated fields also. But irrigated intercropping is common in only a few of the villages. About 37% of the cropped land planted with sole crop receive irrigation compared to 4% of the intercropped land. Therefore, we would expect sole crops to receive more fertilizer

Table 12. Proportion of local (LV) and high yielding (HYV) cultivars receiving FYM and fertilizer, and mean level of nutrients use in seven study villages of India's SAT, 1982-84.

Particular	Local		HYV	
Share in cropped area (%)	77	(32-100)	23	(0-68)
Share in use of total FYM (%)	56	(20-100)	44	(0-80)
Share in use of total fertilizer (%)	31	(9-100)	69	(0-91)
Share of FYM in use total nutrients (%)	47	(30-100)	24	(0-44)
Proportion of cropped area:				
Irrigated (%)	9	(1-16)	48	(0-100)
Manured (%)	17	(5-26)	20	(0-32)
Fertilized (%)	19	(0-58)	76	(0-98)
Mean level of total NPK (kg/ha of cropped area) from:				
FYM	6	(3-12)	12	(0-25)
Fertilizer	7	(1-26)	45	(0-74)
Total	13	(4-38)	57	(0-84)

Figures in parenthese are ranges of mean application levels across the seven villages.

F2_9

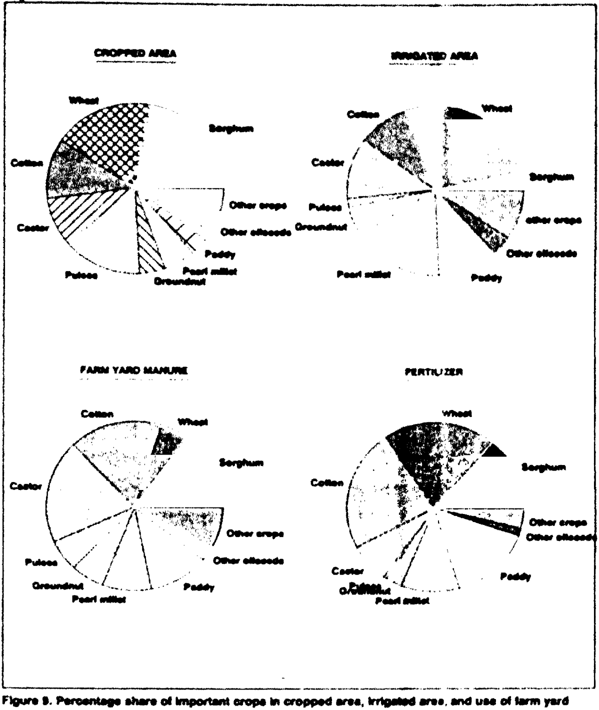

Figure 9. Percentage share of important crops in cropped area, irrigated area, and use of farm yard manure and fertilizer in the villages, 1982-84.

Table 13. Proportion of plots planted with pulses as one of the important components in intercropping system in seven study villages of India's SAT, 1982-84.

Crop combinations	Percentage of total plots
Cereals planted with:	
Cereals	9
Pulses	32
Others	31
Pulses planted with:	
Pulses	6
Others	10
Oilseeds planted with:	
Oilseeds	6
Others	4
Plots intercropped with pulses as atleast one components	50

than an intercrop. That expectation is confirmed in Table 14 On average, a larger (37%) proportion of sole crops received fertilizer compared to intercrop (28%). There was not such a sharp difference in the proportion of cropped area receiving FYM. About 16% of the sole crops received FYM compared to 19% of the intercrops.

In almost all the villages, most (72%) of the fertilizer and FYM (57%) were applied to sole crops, as larger proportion of the sole cropped area received irrigation and planted with HYV's, compared to intercrops. The only exception was Kanzara where intercropping was quite high (78%) and a larger proportion of FYM was applied to the intercrop (Figure 10). In this village, cotton-based intercropping is prevalent.

Farm Size

Size of land holdings operated by the farmers is supposed to be positively associated with fertilizer use. It is expected that large farmers with better access to credit as well as higher incomes apply more fertilizer to their crops compared to resource poor small farmers.

Farm size was defined as the operational holdings (Owned plus leased-in/shared-in minus leased-out/shared-out land). Therefore, farm size is specific to each village and not necessarily comparable with the commonly accepted definitions of farm size in the Farm Management studies in India. All the cultivating households in each village were divided equally into three groups to represent small, medium, and large farmer.

On average, large farmers cultivated about 57 to 80% of the cropped land compared to 5 to 11% by the small farmers in these villages. Similarly, most of the fertilizer (64%) and FYM (73%) was used by the large farmers. However, in some of the villages the proportion of fertilizer used by small farmers was quite high compared to their share in cropped area (Table 15).

It is clear from Table 15 that on average 18% of the cropped area of small farmers received fertilizer (either alone or in combination with farm yard manure) compared to medium (29%) and large farmers (35%). But at the same time about 66% of the cropped area of small farmers

Table 14. Proportion of sole and intercropped plots receiving FYM and fertilizer, and mean level of nutrients use in seven study villages of Indai's SAT, 1982-84.

Particular	Sole crop		Intercrop	
Share in cropped area (%)	50	(22-72)	50	(28-78)
Share in use of total FYM (%)	57	(32-85)	43	(15-68)
Share in use of total fertilizer (%)	72	(61-100)	28	(0-39)
Share of FYM in use of total nutrients (%)	28	(18-95)	43	(26-100)
Proportion of cropped area				
Manured (%)	16	(5-28)	19	(5-34)
Fertilized (%)	37	(1-79)	28	(0-62)
Mean level total NPK (kg/ha of cropped area) from				
FYM	9	(3-17)	7	(3-17)
Fertilizer	24	(1-57)	9	(0-26)
Total	33	(4-69)	16	(4-36)

Figures in parenthese are ranges of mean application levels across the seven villages.

F2_10

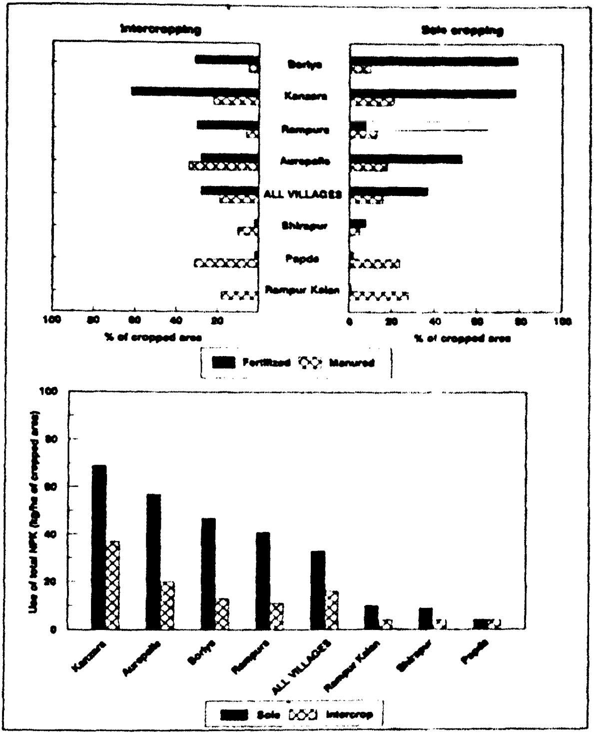

Figure 10. Percentage of sole and intercropped area fertilized and manured, and mean use of total NPk (kg/ha of cropped area), 1982-84.

Table 13. Proportion of cropped area irrigated, manured and fertilized and mean level of total NPK (kg/ha of cropped area) use by farm size class in seven study villages of India's SAT, 1982-84.

Particular	Small farm	Medium farm	Large farm
Share in total cropped area (%)	10 (2-17)	21 (10-30)	69 (54-83)
Share in use of total FYM (%)	9 (6-17)	27 (12-44)	64 (48-82)
Share in use of total fertilizer (%)	4 (0-8)	23 (13-100)	73 (0-87)
Share of FYM in total use of nutrients (%)	51 (21-100)	30 (19-89)	27 (14-100)
Proportion of total croped area			
Irrigated (%)	10 (0-34)	18 (0-49)	19 (3-44)
Manured (%)	17 (10-35)	21 (8-34)	16 (5-34)
Fertilized (%)	18 (0-64)	29 (1-57)	35 (0-65)
Mean level of total NPK (kg/ha of cropped area) from:			
FYM	10 (3-27)	8 (4-14)	8 (4-18)
Fertilizer	9 (1-38)	17 (1-31)	21 (0-39)
Total	19 (2-48)	25 (3-40)	29 (4-54)

Figures in parenthese are ranges of mean application levels across the seven villages.

did not receive any nutrients either from farm yard manure or fertilizer compared to medium (61%) and large farmers (62%). This is not unexpected as only 10% of the cropped area of small farmers received irrigation compared to medium (18%) and large farmers (19%). In most of these villages these farm size differences in fertilizer incidence and use intensity are not that large (Appendix 10 and Figure 11). The main difference was in Aurepalle where large farmers had greater access to irrigation than small farmers.

Comparison of the mean level of nutrients application across farm size classes by simple 't' tests indicates that in most of the villages there were no significant differences in the level of nutrients application between farm size classes (Table 16). In drought-prone villages (Papda and Rampur Kalan) and Shirapur, where postrainy season cropping is predominant, these farm size differences were not significant as fertilizer use was negligible. In irrigated villages of Aurepalle and Rampura these farm size differences were much sharper and were mainly attributed to differential access to irrigation between large and small farmers. There was more parity in the coverage of FYM across farm size classes (Figure 11). Small farmers relied as much on FYM for nutrients application as large farmers.

DETERMINANTS OF FYM AND FERTILIZER USE

The preceeding discussion suggests that a multiple factors influence the farmer's decision on application of nutrients. Any single factor alone cannot fully explain this behaviour. Moreover, the farmers's behaviour of nutrients application also differ at the household and plot level. Therefore, two separate analysis were carried out to estimate the effects of different factors explaining application of FYM and fertilizer at and plot level. Because many farmers of the dependent variable is clustered at zero for a number of observations, to avoid the bias in the estimated coefficients of this truncated model which would result from estimation by ordinary least squares (OLS), the maximum likelihood Tobit technique was used (Amemiya 1973; Tobin 1958; McDonald and Moffitt 1980; Ziemer and White 1981; Patrick 1988).

Table 16. Pairwise comparison of mean level of total NPK (kg/ha of cropped area) in different farm size classes in seven study villages of India's SAT, 1982.84.

Village	Small farm VS Medium farm	Small farm VS Large farm	Medium far VS Large farm
	Pair wise comparison between farm size		
	-------	't' values	----------
Aurepalle	-0.72	-3.06 **	-4.64 **
Shirapur	-1.81	-1.30	1.71
Kanzara	-0.04	-1.65	-2.45 **
Boriya	-0.01	-0.88	-1.36
Rampura	-2.92 **	-3.40 **	-1.59
Rampur Kalan	-1.72	-1.86	-0.96
Papda	-1.02	-1.13	0.20
All Villages	-3.05 **	-5.82 **	-6.50 **

* and ** indicates significant differences in the mean level of toal NPK use among farm sizes at .05 and .01 level of signicance.

The negative signs indicates that the first variable in the comaprison has lower mean that the second one.

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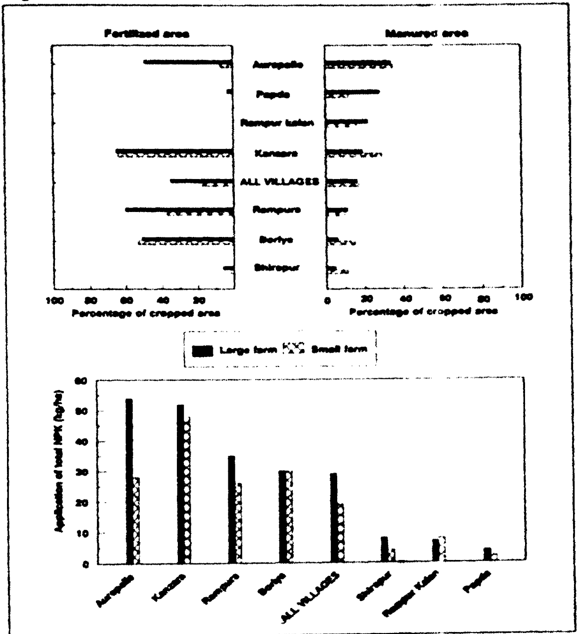

Figure 11. Proportion of cropped area manured and fertilized and mean level of total NPK (Kg/ha of cropped area) by farm size class in seven villages, 1983-84.

Farm Level

The dependent variables used in the analysis were level of total NPK (kg/ha) from fertilizer and FYM. The important household level associated factors influencing level of fertilizer/FYM use were total wealth, number of livestock, operated holding, schooling years of the farmers, the age of the farmer as proxy for his experience, the traditional caste of the farmer. In addition to the farmer specific characteristics some other factors such as value of the land (Rs/ha) refelecting for the quality of land cropped, proportion of cropped area receiving irrigation and proportion of cropped area planted in rainy and post rainy season were also included in the model. Since most of the fields during summer season are planted under irrigated condition and receive higher doses of fertilizer therefore, it was assumed that seasonal cropping alone might not explain fully the application of fertilizer and FYM. To avoid this bias of irrigation and seasonal cropping and irrigation interactions were also used in the model. Besides this the village dummies were included to explain the environmental differences like rainfall pattern, infrastructure, level of technological development, nearness to market, etc., and cropping year dummies to capture the effect of year to year fluctuations in climate specially rainfall.

It was expected that village environment representing level of technological development and infrastructure, rainfall pattern, soil type, and cropping pattern influence the level of fertilizer and FYM use. Those villages with assured rainfall and better quality of soil and higher level of technological development are expected to apply fertilizer and FYM in larger areas than those villages where rainfall is low and erratic, soils were poor, and adoption of new technology was low. Similarly the extent of seasonal cropping and status of irrigation also are expected to influence fertilizer use decisions. Compared to unirrigated fields cropped during kharif season irrigated fields cropped during rabi and summer seasons are expected to receive more fertilizer. It was also expected that educated heads of households and higher caste farmers use more fertilizer compared to the low caste and uneducated farmers.

At the aggregate level mean level of total nutrients (N+P+K) from fertilizer and FYM was 11 and 8 kg per ha of cropped area, respectively. The results presented in Table 17 indicate that most of the coefficients show the expected sign. But a few of them were not as important as expected. It is clear from Table 17 that increased irrigation alone does not significantly influence the level of nutrients application either from fertilizer or FYM. This is again in conformity with the earlier observation that all the irrigated land do not receive fertilizer. However, the effect of irrigation becomes stronger once the seasonal cropping interact with irrigation.

Farmers apply higher doses of fertilizer in irrigated fields planted during rainy and postrainy season compared to unirrigated fields planted during rainy and postrainy season. Increased irrigation during postrainy and summer season are likely to significantly increase the level of fertilizer use. But there was no significant difference in the level of FYM use across seasons

Higher caste farmers apply higher doses of fertilizer and FYM to their fields than the low caste farmers. The more years of schooling of farmers also significantly increase the level of fertilizer application but not the level of FYM. Village dummies were important in expalining the level of fertilizer and FYM use. Year dummies indicate increasing trend in level of fertilizer application over years specially after 1980. But application of FYM does not show any such clear trend. This is not unexpected as use of FYM was not as regular as fertilizer. Quality of land (explained by the value of land), size of farm, wealth and age of the farmers were not important in explaining the level of fertilizer and FYM use. Number of livestock was positively and significantly associated with the level of fertilizer and FYM use.

Plot Level

In another regression same set of variables were tried to estimate their effect on the level of nutrients application at the plot level. The variables were level of total NPK dependent per ha from fertilizer and FYM. The independent variables included in the model were both binary and continuous. Most of the explanatory variables used in the previous model were

Table 17. Farm level determinants of mean level of FYM and fertiliser use in seven study villages of India's SAT, 1982-84. (Tobit regression)

Variable	Fertiliser: Mean (% share)	Fertiliser: Regression coefficient	Fertiliser: Elasticity	Farm yard manure: Regression coefficient	Farm yard manure: Elasticity
VILLAGE DUMMY (%)					
VILD1 (Aurepalle)	0.221				
VILD5 (Shirapur)	0.206	-29.36 **	-0.400	-27.78 **	-0.206
VILD6 (Kanzara)	0.221	19.11 **	0.278	-22.49 **	-0.248
VILD7 (Boriya)	0.099	-1.27	-0.008	-30.68 **	-0.152
VILD8 (Rampura)	0.101	5.09	0.034	-21.45 **	-0.108
VILD9 (Papda)	0.078	-61.25 **	-0.316	-38.15 **	-0.149
VILD10 (B' Kalan)	0.074	-58.69 **	-0.288	-33.31 **	-0.124
CASTE DUMMY (%)					
CASTE1	0.437				
CASTE2	0.191	1.39	0.020	3.65	0.035
CASTE3	0.217	-4.63	-0.066	-0.18	-0.002
CASTE4	0.135	-19.55 **	-0.174	-7.68 **	-0.052
YEAR DUMMY (%)					
1975/76	0.068				
1976/77	0.061	3.65	0.015	-4.58	-0.014
1977/78	0.066	2.75	0.012	-7.93	-0.026
1978/79	0.065	5.77	0.025	-19.65 **	-0.064
1979/80	0.067	5.28	0.024	-11.05 **	-0.037
1980/81	0.109	12.70 **	0.092	-0.27	-0.001
1981/82	0.144	10.58 **	0.100	-7.40	-0.053
1982/83	0.336	10.84 **	0.100	-4.37	-0.030
1983/84	0.140	20.43 **	0.189	7.80	0.055
1984/85	0.142	20.47 **	0.192	7.00	0.050
IRRIGATION (%)	14.72	0.14	0.133	0.13	0.094
SEASON X IRRIGATION (%)					
KHARIF DRY	56.206				
KHARIF WET	4.832	0.57 **	0.183	-0.25	-0.602
RABI DRY	28.901	0.19 **	0.358	-0.06	-0.085
RABI WET	6.217	0.52 **	0.214	-0.06	-0.019
SUMMER WET	3.449	0.34 **	0.077	0.34	0.058
SCHOOLYR (Years)	3.108	-0.53 *	-0.109	-0.19	-0.030
LANDVAL (Rs 000/ha)	'2.630	-0.02	-0.084	-0.04	-0.127
LIVESTOCK (Number)	4.765	0.64 **	0.201	0.79 **	0.188
OPAREA (ha)	5.305	0.05	0.019	-0.20	-0.052
AGE (Years)	47.738	-0.71	-2.250	0.06	0.155
AGESQ (100 Yrs)	24.118	0.70	1.121	-3.17	-0.038
WEALTH (Rs 000)	51.984	0.60	0.205	0.02	0.061
WEALTH squared	5976.00	-0.16	-0.064	-0.01	-0.004
Constant		-2.56		-15.35	
Log-likelihood function		-3087.28		-3299.51	
R^2		0.475		0.152	
Predicted probability of Y > limit given average X (1)		0.403		0.414	
Observed frequency of Y > limit is		0.486		0.468	
Number of observation					
Limit		678		701	
Non-Limit		641		618	
Total		1319		1319	

* and ** indicate significant at 0.1 and 0.05 level of significance.

included in this model also to compare that how far these factors influence differently the level of fertilizer and FYM use at farm household and plot level.

The results presented in Table 18 indicates that additional one hectare of irrigated land increases the consumption of 56 kg of nutrients (NPK) from fertilizer and 44 kg (NPK) from FYM compared to unirrigated fields. Also the irrigated fields have the higher (0.57) elasticity of fertilizer use than the FYM (0.24).

The Higher caste farmers apply higher doses of fertilizer and FYM than low caste farmers. But the elasticities for application of both FYM and fertilizer was very low. The village environment play an important role in determining the application of fertilizer application and FYM. Irrigated and assured rainfall villages received higher doses of fertilizer than the drought prone villages with unreliable rainfall and low level of technological development in terms of low irrigation and poor adoption of HYV. However, in irrigated villages farmers apply more fertilizer than FYM.

Education and age of farmers significantly influence the application of fertilizer and FYM. Farmers with more wealth did apply higher doses of fertilizer and FYM. Farm size and availability of livestock were not very important in determining the application of fertilizer but they were positively associated with the application of FYM. The quality of land, measured as the value of land, was positively and significantly associated with the application of fertilizer but not with the application of FYM. This is in conformity with the farmers' perception that FYM application is a soil improvement strategy rather than increasing soil fertility. The non-significant effect of number of livestock and farm size is mainly because their effect was neutralized by irrigation and wealth. It is evident that most of the users of nutrients were the large farmers who had more irrigated land and belong to higher caste. However, value of land, which explains the quality of land, indicate that because of higher production potential more fertilizer is used in those plots which have better quality land. In most of the villages the value of land was quite high due to access to irrigation which adjusts for the quality of land hence increase the response to fertilizer.

Table 18. Plot level determinants of mean level of FYM and fertilizer use in seven study villages of India's SAT, 1982-84.
(Tobit regression)

Variable	Mean (% share)	Fertilizer: Regression coefficient	Fertilizer: Elasticity	Farm yard manure: Regression coefficient	Farm yard manure: Elasticity
VILLAGE DUMMY (%)					
VILD1 (Aurepalle)	0.124				
VILD3 (Shirapur)	0.145	-84.442 **	-0.317	-64.342 **	-0.109
VILD5 (Kanzara)	0.117	46.852 **	0.142	-2.536	-0.003
VILD7 (Boriya)	0.186	-14.965 **	-0.061	-96.934 **	-0.178
VILD8 (Rampura)	0.252	-27.201 **	-0.180	-39.234	-0.115
VILD9 (Papda)	0.100	-94.474 **	-0.244	48.969 **	0.057
VILD10 (R' Kalan)	0.104	-145.980 **	-0.395	15.210	0.018
CASTE DUMMY (%)					
CASTE1	0.623				
CASTE2	0.178	1.909	0.007	12.523	0.026
CASTE3	0.154	-7.640	-0.030	8.800	0.016
CASTE4	0.045	-17.072	-0.020	-3.842	-0.002
IRRIGATION (%)					
IRIG1 (Dry)	0.704				
IRRIG2 (Wet)	0.296	56.688 **	0.435	67.720	0.233
YEAR DUMMY (%)					
YRD1 (1982)	0.336				
YRD2 (1983)	0.334	21.220 **	0.184	35.920 **	0.139
YRD3 (1984)	0.330	21.830 **	0.187	35.693 **	0.137
SEASON X IRRIGATION (%)					
KHARIF DRY	0.466				
KHARIF WET	0.105	30.030	0.062	53.446	0.066
RABI DRY	0.241	-18.095 **	-0.113	-63.351 **	-0.178
RABI WET	0.109	47.342	0.135	-132.780	-0.168
SUMMER WET	0.079	39.432	0.081	13.506	0.012
SCHOOLYR (Years)	4.187	-1.199 **	-0.130	-0.468	-0.003
LANDVAL (Rs 000/ha)	11.413	0.131 **	0.389	-0.211	-0.280
LIVESTOCK (Number)	6.320	0.538	0.094	1.308	0.099
OPAREA (ha)	7.106	-0.519	-0.096	-3.792 **	-0.313
AGE (Years)	49.580	-2.414 **	-3.107	-1.755	-1.012
AGESQ (100 years)	25.738	0.022 **	1.481	0.014	0.422
WEALTH (Rs 000)	106.930	43.680	0.121	12.936	0.161
Constant		-0.476		-98.140	
Log-likelihood function		-8882.976		-5363.251	
R^2		0.318		0.041	
Predicted probability of Y > limit given average X (I)		0.217		0.139	
Observed frequency of Y > limit is		0.355		0.165	
Number of observation					
Limit		2619		3375	
Non-Limit		1442		580	
Total		4061		3955	
Mean level of use (kg/ha)		20		14	

* and ** indicate significant at 0.1 and 0.05 level of significance.

Post-monsoon cropping is possible mainly under assured irrigation condition, which is limited in these villages. However, irrigated fields in rainy and postrainy season received about 15 and 30 kg more fertilizer respectively than the unirrigated fields in rainy season. But unirrigated fields in postrainy season received about 11 kg less fertilizer than the unirrigated fields in rainy season. This clearly indicates that in the absence of irrigation postrainy season fields receive very little fertilizer.

The application of FYM indicate different pattern. In high rainfall kharif fallowing areas application of FYM is common compared to irrigated and assured rainfall areas. But application of FYM in irrigated fields in rainy season is quite high compared to irrigated fields in rainy and postrainy season. This shows that application of FYM is done mainly in the beginning of the rainy season on unirrigated fields. Number of livestock, value of land, and education of the head of households were weakly but positively associated with higher FYM use. Year dummies indicate that application of FYM is not as regular as fertilizer but over years fertilizer application is likely to increase.

The comparison of the effects of farmer specific variables on the level of fertilizer and FYM use at households and plot levels indicates that a farmers with more irrigated land do not necessarily use higher doses of fertilizer. However in irrigated fields they apply higher doses than the dry fields. Similarly the season and irrigation interaction at farm hosuehold level suggests that compared to unirrigated land planted during rainy season farmer might apply higher doses of fertilizer in other seasons both under irrigated and unirrigated condition. But it does not seem true at the plot level. Compared to unirrigated fields planted during rainy season irrigated fields in postrainy season receive higher doses of fertilizer. The farm size, wealth, and value of land are not important at household level but farmers will apply higher doses of fertilizer to the fields with better quality of land possibly because of better response to fertilizer. Simialrly expereinced farmers apply higher doses of fertilizer to selected fields but not necessarily higher doses of fertilizer to all thier fields. However, farm size was not important both at the household and plot level. Number of livestock also significantly influence the doses of fertilizer at household level but at plot level its role is not important. Increased schooling significantly influence the doses of fertilizer both at household and plot level.

Village environment also suggest that in medium rainfall and relatively more irrigated villages farmers might not apply higher doses of fertilizer to all of their fields compared to those villages with higher irrigation and reliable rainfall but would apply lower doses of fertilizer to many fields.

CONCLUDING REMARKS

The foregoing analysis clearly indicates that in most of the villages of India's SAT fertilizer use is very low, and a large proportion of cropped land do not receive any nutrients from any of the two main sources namely farm yard manure and fertilizer. Most of the farmers apply low doses of nutrients to their crops. Most of the fertilizer is consumed by superior cereals and high value crops planted mainly as high yielding cultivars. Fertilizer is positively associated with higher level of irrigation but in a few of the villages even irrigated fields also do not receive any nutrients. In contrast quite a large portion of unirrigated land do receive nutrients. Application of farm yard manure is common in unirrigated fields but it is applied more with the idea of soil-ammendment rather soil-improvement strategy.

Fertilizer use is significantly influenced by the village environment indicating the level of technological development and infrastructur, and access to irrigation. Within the villages, farm size differences in the level of nutrients use are not much. Much of the variability in the level of nutrients use across villages and farmers are due to inter-household variation whereas village environment account for more than 1/4 of the total variation.

This suggests that there is enough scope for increasing the use of fertilizer in the dryland agriculture if some major breakthrough can come from crop improvement in developing for fertilizer responsive varities. However, in mainly rainfed regions with postrainy season cropping the possibilities of increased fertilizer use seem to be bleak due to poor response of fertilizer on yields in the absence of adequate soil moisture and irrigation.

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Appendix 1. Location of study villages in India's SAT.

Villages	District	State	Distance from ICRISAT center (Kms)	Coordinates E		N	
Aurepalle	Mahbubnagar	A. P.	70	78	39'	16	52'
Dokur	"	"	120	78	50'	16	36'
Shirapur	Sholapur	Maharashtra	340	75	45'	17	45'
Kalman	"	"	350	75	49'	17	52'
Kanzara	Akola	Maharashtra	550	77	23'	20	39'
Kinkheda	"	"	555	77	28'	20	36'
Boriya	Sabarkantha	Gujarat	1300	72	54'	23	14'
Rampura	"	"	1310	72	55'	23	17'
Papda	Raisen	M. P.	1210	78	17'	23	27'
Rampur Kalan	"	"	1220	78	14'	23	21'

Appendix 2. Important characteristics of farming in the selected regions of India's SAT, 1982-84.

Particular	Mahbubnagar	Sabarkantha	Akola	Sholapur	Raisen
Soiltype	Shallow to medium alfisol	Entisol	Medium to deep vertisol	Medium to deep vertisol	Medium deep vertisol
Rainfall (mm)	760	760	885	665	1200
variation in rainfall (CV %)	35	33	23	34	39
Average family size (No.)	6.0	5.3	5.8	6.6	6.0
Average size of holding (ha)	2.1	2.8	4.1	5.2	5.3
Number of bullocks per 10 ha of land	3.4	3.5	2.5	1.7	4.8
Cropping system [1]					
Intercropping	28	47	78	33	29
Irrigation	40	38	10	12	3
Rabi cropping	10	7	3	67	83
Important crops	Sorghum Castor Paddy Pulses	P.millet Castor Wheat Cowpea	Sorghum Cotton Pigeonpea Greengarm	Sorghum Pigeonpea Chickpea Sunflower	Wheat Chickpea Soybean Linseed

[1] Refers to percentage of total cropped area.

Appendix 3. Number of farmers using different level of nutrients (NPK in kg/ha of cropped area) in seven study villages of India's SAT, 1982-84.

Village	Total no. of farmers	Level of fertilizer use (NPK kg/ha of cropped area)							
		0	< 10	11-20	21-30	31-40	41-60	61-80	>80
		Number of farmers							
Aurepalle	31	4		4	7	5	7	3	1
Kanzara	34	3	1	4	9	2	8	4	3
Boriya	31	2	1	5	13	3	5	1	1
Rampura	29	2	2	4	5	5	8	1	2
Shirapur	28	10	16	1	1				
Rampur Kalan	25	6	14	5					
Papda	28	10	18						
All villages	206	37	52	23	35	15	28	9	7

Appendix 4. Share of FYM in total nutrients (NPK) applied in unirrigated and irrigated fields in seven study villages of India's SAT, 1982-84.

Village	Share (%) of FYM in total NPK used in		
	Unirrigated	Irrigated	Total
Rampur Kalan	100	0	97
Papda	78	100	79
Shirapur	98	40	59
Aurepalle	81	27	49
Kanzara	27	15	24
Rampura	44	20	24
Boriya	39	18	23
All villages	49	21	34

Appendix 5. Number of farmers having access to irrigation in seven study villages of India's SAT, 1982-84.

Village	Total no. of farmers	Level of irrigation (% of cropped area)							
		0	<10	11-20	21-30	31-40	41-60	60-80	>80
Papda	28	26		1			1		
Rampur Kalan	25	20	1	2	1	1			
Aurepalle	31	20	1		5	2	2	1	
Kanzara	34	20	5	3	1	3	2		
Shirapur	28	13	5	4	3	1	1	1	
Boriya	31	5	2		3	5	13	2	1
Rampura	29	6			2	3	18		
All villages	206	110	14	10	15	15	37	4	1

Appendix 6. Percentage of cropped area irrigated and share (%) of total FYM and fertilizer used in irrigated fields in seven study villages of India's SAT, 1982-84.

Village	% of total cropped area irrigated	% share of total FYM and fertilizer used in irrigated fields	
		FYM	Fertilizer
Aurepalle	21	32	84
Shirapur	11	23	98
Kanzara	14	18	32
Boriya	40	59	82
Rampura	44	72	89
Papda	1	2	0
Rampur Kalan	2	0	100
All villages	18	34	65

Appendix 7. Percentage of cropped area manured and fertilized, and mean level of total NPK (kg/ha of treated area) in kharif and rabi season in seven study villages of India's SAT, 1982-84 (dry plots only).

Village	% of cropped area				Mean dose of total NPK (kg/ha of treated area)			
	Manured		Fertilized		Manured		Fertilized	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Shirapur	1.7	7.6	0	1.0	13	29	0	19
Rampur Kalan	34.9	17.8	0	0	44	21	0	0
Papda	33.7	25.3	0	2.7	13	11	0	29
Aurepalle	30.8	11.3	33.0	24.6	75	67	36	29
Kanzara	22.1	0	62.7	14.4	75	0	54	24
Boriya	5.3	0	29.9	38.6	86	0	26	50
Rampura	6.4	1.5	25.6	50.4	82	97	31	13
All villages	18.7	15.5	34.2	4.1	63	19	40	22

Appendix 8. Share of HYVs in total cropped area, proportion of cropped area irrigated, and level of FYM and fertilizer use in local and HYV in seven study villages of India's SAT, 1982-84.

Village	% share of HYV in total cropped area	% of cropped area irrigated		% share of total FYM used in HYV	% of total fertilizer used in HYV
		Local	HYV		
Kanzara	20	13	18	23	44
Rampura	47	14	76	64	91
Boriya	68	16	51	80	91
Aurepalle	53	11	29	70	84
Shirapur	1	11	100	0	7
Rampur Kalan	0	2	-	0	-
Papda	1	1	-	0	-
All villages	23	9	48	44	69

Appendix 9. Extent of intercropping and share of intercropping in use of total FYM and fertilizer in seven study villages of India's SAT, 1982-84.

Village	% of total cropped area intercropped	% share of intercrop in total use of	
		FYM	Fertilizer
Aurepalle	46	47	7
Shirapur	48	47	6
Kanzara	78	68	39
Boriya	52	36	18
Rampura	28	15	6
Papda	38	38	33
Rampur kalan	51	29	0
All villages	50	43	28

Appendix 10. Share (%) of different farm size class in total irrigated area, use of FYM and fertilizer, and level of FYM and fertilizer use in seven study villages of India's SAT, 1982-84.

Village	% of cropped area irrigated			Share of total FYM used in (%)			Share (%) of total fertilizer used in		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
Aurepalle	0	5	29	11	29	60	a	13	87
Kanzara	12	10	15	6	12	82	6	14	80
Boriya	25	49	37	17	35	48	8	36	55
Rampura	34	44	43	6	35	59	3	33	64
Shirapur	8	15	10	8	44	48	a	46	53
Papda	0	0	3	7	30	63	0	29	71
Rampur kalan	2	1	3	13	33	54	0	100	0
All Villages	10	18	19	9	27	64	4	23	73

a: refers to less than 1% share in total use of fertilizer.