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Incentives for Adopting Soil Test Based Fertiliser Use: Evidences from ABC Trials†

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I

THE ISSUE

Insufficient production of foodgrains and their large scale imports in the early sixties made it abundantly clear that the agricultural sector had to perform better (Brahmananda and Vakil, 1960; Mellor, 1976). The new development strategy emphasised land augmenting technological changes in agriculture and stress was laid on identifying the crucial factors which could facilitate this process (Mellor and Lele, 1971; Hayami and Ruttan, 1971). Thus the modern agricultural inputs which have synergistic effects on yield became the focal point of the strategy. As a result, the importance of chemical fertilisers grew enormously.[1]

The economic rationale for the increasing importance of fertilisers was provided by trials conducted on cultivators' fields on different crops during the pre-high-yielding varieties (HYVs) period.[2] Introduction of HYVs and hybrid varieties (HBs) brought an optimism about fertiliser response superiority of modern varieties (MVs) over traditional varieties (TVs) (Kanwar, 1972 *a*, 1973 *a*, 1973 *b*). The main points established (Minhas and Srinivasan, 1966; Cummings, Jr., 1968; Parikh, 1978; Vaidyanathan, 1978) were: (*a*) that MVs had higher response than TVs, (*b*) that the full benefit of MVs could be achieved when the synergistic potential of a package of inputs was exploited and (*c*) that among the fertiliser nutrients most widely deficient in Indian soils were nitrogen followed by phosphate and then potash.

Policies based on such understanding resulted in concentration on the use of nitrogenous fertiliser on HYVs along with intensive use of assured water (Government of India, 1965, 1966). In turn, this led to (*a*) lopsided research efforts at the cost of unirrigated agriculture (Jodha, 1989) and (*b*) concentration and excessive use of nitrogenous fertiliser on some irrigated crops and areas (Shah and Sah, 1989; Desai, 1990). The outcome was widespread inefficiency in fertiliser use.

Till recently, improving fertiliser use efficiency had been an agronomist's concern.[3] But the situation changed due to the oil crisis of the seventies which attracted economists towards these issues. Two aspects seem to have been prominent in this context: (*i*) soil-crop-fertiliser nutrient management (Kanwar, 1972 *a*; Dhnu, 1975; Velayutham, 1985) and (*ii*) time and method of fertiliser use (Have, 1971; Bains, 1974; Singh and Singh, 1975; Prashad, 1975).

Experimental results have shown that economics of fertiliser use can be improved if fertiliser use is adjusted according to the fertility status of the field, for the economic rate of nutrient use is negatively associated with the fertility status of the soil (Ramamoorthy

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and Pathak, 1968; Ramamoorthy *et al.*, 1969). Similarly, management practices, especially for application of fertiliser are also important for increasing yield response. Thus it is necessary to identify the best combination of farm practices and fertiliser requirement to optimise nutrient absorption as well as yield under varying soil productivity. Soil test services play a crucial role in identifying this combination for specific farm situations.[4]

Although the economic gains of adopting individual farm specific soil test based recommendations over taluka level recommendations are well established on research stations, the follow-up of the implementation of such recommendations at the farm level has been discouraging. A recent study shows that only a third of the cultivators are aware of soil testing services; and only one out of ten farmers have ever got their soils tested (Shah and Sah, 1989). Research on adoption of soil test based recommendations in the late seventies showed (Babaria, 1975) that only a minority of farmers, whose soils were tested, based their fertiliser use on these results; nine out of ten farmers did not even receive the results of their soil tests. The situation has not changed significantly even after two decades; nearly half of the farmers whose soil samples were collected do not receive the report (Sah and Shah, 1990).

The reasons for the farmers' non-adoption may be sought in terms of (*a*) the nature of economic gains from adoption of soil test based recommendations observed through field demonstrations or (*b*) farmers' rationale for their fertiliser use behaviour and (*c*) appropriateness of recommendations as well as other supply services. The main focus of this paper is confined to the first two aspects.[5] The two main objectives of this analysis are as follows: firstly, to estimate and evaluate the potential benefit that would be accruing to farmers if they shifted from 'blanket' (or taluka level) to farm specific soil test based recommendations. This has been done with the help of ABC trials data for different crops. The analysis of potential benefits would help evolve a crop hierarchy suggesting the possible sequence of adoption. And secondly, to examine how the potential benefits have influenced the actual adoption amongst farmers. This is based on primary survey of 330 sample farmers located in high fertiliser using areas. These farmers are different from those on whose farms ABC trials were conducted. The analysis will help in the understanding of the farmers' adoption behaviour.

Framework

ABC trials are carried out to demonstrate the benefits accruing to farmers as a result of adoption of soil test based recommendations. These trials are arranged on three plots on the farmers' field with varying fertiliser use: (*i*) soil test based recommendations Plot A, (*ii*) blanket recommendations Plot B and (*iii*) farmers' own practices Plot C. With all other farm practices remaining the same, the yield differentials between A and B sub-plots can be attributed to the difference in efficiency of fertiliser use.

Given the efficacy of supply services, adoption of soil test based recommendations for a crop depends on the size and certainty of marginal returns associated with the movement from blanket fertiliser use to soil test based levels. While the average of marginal returns over the years and across farms could become the measure of the size of economic incentives, uncertainty could be captured through coefficient of variations in the marginal returns. Considering that the effect of the abnormal years was independent of crop technology, it was assumed that farmers view uncertainty associated with a technology through yield variations across farms in most adverse years. This is not a heroic assumption, for, learning by experimenting of uncertainty reduction involved a cost only for the early adopters; efficient exchange of experiences, for a large set of cultivators, reduces the time and cost involved in acquiring the essential information related to cultivation (Feder and O'Mara, 1984). Thus if the average of marginal returns for a crop was high and certain, more farmers would move towards the levels of soil test based fertiliser use relatively faster than they would for a crop where changes in fertiliser use is associated with low and uncertain returns. The limit to increasing fertiliser use could be set by the soil test based recommendations, provided proper management practices were also adopted. Unless farmers' perceptions are tuned to understand the limits to economic incentives, over-use of fertiliser could be widespread in a situation where marginal returns are high and certain.

II

ABC DEMONSTRATIONS

Using the above framework, an attempt is made in this section to examine the economic advantage of farm specific soil test based recommendations by using the results of ABC trials conducted during 1987-88 and 1988-89 in Gujarat. In all, 208 trials were conducted during this period, out of which the results of 191 trials covering seven major crops were analysed.

Coverage of Crops and Farmers

Table I gives the distribution of number of trials conducted for different crops along with the status of fertiliser use and net returns across three plots. It clearly revealed that: (*i*) the

TABLE I. CROPWISE DISTRIBUTION OF NUMBER OF ABC TRIALS AND RELATIVE RATES OF FERTILISER USE AND NET RETURNS ON DIFFERENT PLOTS (COMBINED FOR 1987-88 AND 1988-89)

Crops	Number of ABC trials				
	Total	Fertiliser use		Net returns	
		A>B	B>C	A>B	B>C
(1)	(2)	(3)	(4)	(5)	(6)
Wheat (I)	80	52 (119)[a]	67 (139)[b]	56	75
Paddy (I)	28	26 (115)	20 (109)	28	25
Paddy (UI)	7	7 (120)	7 (141)	7	6
Maize (I)	16	7 (97)	14 (187)	16	14
Maize (UI)	6	5 (127)	5 (135)	5	6
Bajra (I)	10	9 (133)	9 (257)	10	10
Groundnut (I)	18	9 (89)	12 (132)	18	14
Groundnut (K)	9	7 (147)	2 (90)	9	6
Rapeseed (I)	10	9 (127)	9 (175)	10	10
Sunflower (I)	7	6 (121)	7 (362)	7	7
Total	191	137 (116)[a]	152 (143)[b]	166	173

Source: Directorate of Agriculture, Government of Gujarat, Ahmedabad.

* Excludes 17 trials covering six other crops, *viz.*, bajra-UI (6), cotton (3), potato (3), tobacco (1), pulses (1), jowar (3).

a. Fertiliser use in A as percentage of B.

b. Fertiliser use in B as percentage of C.

K = *Kharif*; I = Irrigated; UI = Unirrigated.

crop coverage was limited to those crops which were not typically known for widespread over-use of fertilisers; for example trials on sugarcane, tobacco, hybrid cotton and potato are rarely conducted; (*ii*) in a majority of cases the level of fertiliser use[6] as well as net returns were higher on plot A than on plot B;[7] (*iii*) the difference in fertiliser use was much larger between B and C than in A and B, indicating a significantly low fertiliser use (about 60 per cent of the actual requirement) among the farmers chosen for ABC trials. Given the fact that the farmers' fertiliser use was very low, comparison between C and B or C and A would bring out only the obvious fact that higher fertiliser use gives better reward. In this process the distinction between simple fertiliser trials (projecting the gains of fertiliser use *per se*) and ABC trials (projecting the efficiency of fertiliser use) is lost.

Since the special objective of these trials was to demonstrate the economic gains resulting from relatively small adjustments in fertiliser use, the relevant comparison would be between A and B. Therefore, the following analysis is confined to the results obtained from these two plots.

Incremental Gains

The additional advantage resulting from changing fertiliser use from the blanket (B) to soil test based (A) recommendations are presented in Table II. A cursory glance at the marginal yield, marginal returns and changes in NPK use revealed: (*i*) Though fertiliser use was higher on soil test based plots, the increase in fertiliser use was not substantial. (*ii*) Despite a marginal change in fertiliser use, the resultant increase in yield and net marginal returns were substantial. (*iii*) The marginal yields and returns varied widely across crops and over locations.

TABLE II. DIFFERENCE IN FERTILISER USE, NET RETURNS AND YIELD BETWEEN SOIL TEST AND BLANKET RECOMMENDATIONS

	Change from B to A		
Crops (1)	Fertiliser use (kg/ha) (2)	Net returns (Rs.) (3)	Yield (kg/ha) (4)
Wheat (I)	36[a] (644)[b]	403 (170)	195 (134)
Paddy (I)	26 (183)	938 (122)	431 (130)
Paddy (UI)	27 (55)	1,513 (81)	676 (61)
Maize (I)	-5.4 (700)	701 (92)	237 (114)
Maize (UI)	31 (87)	189 (400)	220 (256)
Bajra (I)	41 (80)	354 (35)	195 (47)
Groundnut (I)	-6 (147)	862 (159)	174 (89)
Groundnut (K)	18 (103)	940 (104)	231 (78)
Rapeseed (I)	30 (45)	824 (73)	167 (64)
Sunflower (I)	22 (51)	1,282 (58)	250 (54)

K = *Kharif;* I = Irrigated; UI = Unirrigated.
a. Average value of pooled data for 1987-88 and 1988-89.
b. The coefficient of variation (CV) refers to one of the two years which had higher value of CV.

Expected Adoption across Crops

Table III presents classification of some important crops according to the marginal returns and variations in it across plots. Among the fourteen crops for which the ABC trials data

TABLE III. SIZE AND CERTAINTY OF MARGINAL RETURNS DUE TO CHANGING FERTILISER USE TO SOIL TEST BASED RECOMMENDATION FROM BLANKET RECOMMENDATIONS

Marginal returns (Rs./ha)	Variations in net return		
	Low (CV up to 80)	Moderate (CV 80 to 200)	High (CV over 200)
(1)	(2)	(3)	(4)
More than 800	Tobacco I*		
	Paddy UI	Paddy I	
	Sunflower I	Groundnut (K)	
	Rapeseed I		
250-800	Castor I*	Maize I	Cotton (H 4) I*
		Wheat I	Groundnut I
Less than 250	Bajra UI		Maize UI
	Bajra I		

* Based on experiments conducted between 1984 and 1988. For these crops the actual CV is not considered because of the small number of observations. Instead, the judgement is based on the field experience which indicates that yield variations are very high in cotton and low in tobacco and castor.

were available, tobacco, rainfed paddy, irrigated sunflower and rapeseed offered sure and substantial economic incentives for moving towards soil test recommendations. Both rainfed and irrigated bajra, where returns though low were highly risk-free, fell in the second group. The probability of farmers accepting the recommendations for these two groups of crops would be high. Moreover, it is likely that the first group of crops would be prone to excessive use of fertilisers because of the low risk involved. On the other hand, crops like irrigated paddy and groundnut grown in the *kharif* with high marginal returns and moderate risk, depicted an environment where the movement towards soil test based recommendations would be selective to begin with but would spread on all farms subsequently. These crops too were prone to excessive use of fertilisers.

The use of fertilisers for irrigated wheat, maize, cotton and castor offered medium returns; with moderate risk in the case of wheat and maize, low in castor and high in cotton. Farmers' adoption of soil test based recommendations for these crops would be slow with a high probability of lower than recommended use. In castor, however, the adoption rate would be higher than the other crops in this group because of the relative stability of net returns. On the other hand, cotton would have still lower adoption rate because of the relatively more fluctuating yields due to pest attack. Lastly, in unirrigated maize, returns were low and highly uncertain. Except for a few risk-takers, farmers would generally refrain from adopting soil test based recommendations; the actual use would be much lower than the soil test based recommendations.

Correlates of Incremental Yield

Since marginal yield will be much higher at the lower level of fertiliser use as well as yield, incentives to adopt may be better in situations where blanket recommendations are lower than the individual farm specific soil test based recommendations. Thus in order to evolve an adoption pattern for a crop, an attempt was made to understand the yield dynamics at different levels of fertiliser use by working out correlations between incremental yield and the following variables: (*a*) change in fertiliser use, (*b*) base level of fertiliser use and (*c*) level of base yield. It was found that there was no significant correlation between increase in yield and the above variables. This is not surprising, for, the ABC trials data capture only a small section of the entire production surface which itself might be different across locations. Nevertheless, total absence of any correlation even on a portion of the production surface, do suggest a need for a more detailed analysis where discrete groups are created in terms of (*a*) base level yields, (*b*) changes in the level of fertiliser and (*c*) changes in balance of nutrients. The attempt is to explain the yield variations across these groups of plots. Owing to inadequate number of trials in different crops, the analysis is confined only to wheat.

Table IV gives the increase in wheat yield at low, medium and high levels of base yield and base fertiliser use. Table V gives changes in yield with low, medium and high changes in NPK use with and without change in N-P ratio. The following points are noteworthy: Firstly, increments in yield associated with movement from plot B to plot A are significant and are independent of both base yield and base fertiliser use. In other words, significant increase in yield is obtained even at high levels of base yield as well as high levels of base fertiliser use. Secondly, even with negative changes in fertiliser use from plot B to A plot , there is an increase in yield, though incremental yield increases with higher changes in fertiliser use. Thirdly, for a significantly large number of experiments the nutrient balance had changed due to soil test recommendations. The incremental yield was not significantly different in cases where nutrient balance had changed compared to cases where nutrient balance had not changed.

Main Observations

The above analysis highlights the following crucial dimensions of the soil test based recommendations. Economic gains in adopting soil test based recommendations are quite substantial even at very high levels of base yield or fertiliser use. However, it is pertinent to note that the yield gains are subject to wide variations (in terms of CV) across plots. As argued earlier, the lack of correlation between the incremental yield and the incremental NPK may originate partly due to differences in the inherent characteristics of the soils at different locations. But, more importantly, the yield variations are also likely to be due to differences in farm practices adopted by the farmers across different plots.[8] Since variations in inherent soil characteristics can hardly be altered, attention should be paid to the management practices at least on plots A and B.

Since some of these practices, *viz*., number of irrigations, use of farmyard manure and other cultural practices, are often not maintained at the recommended levels, the yield potential of appropriate level and balance of fertiliser use cannot be fully realised. This would perhaps explain why the above analysis (in Table V) does not provide any clear and positive economic incentives resulting from changes in N-P balance. This phenomenon, viewed along with the earlier observation about choosing the farmers using very low fertiliser for conducting these trials, might miss out the special thrust on marginal calibrations in fertiliser use and reflect serious limitations of these demonstrations.

TABLE IV. INCREMENTAL YIELD ACCRUING DUE TO SHIFT FROM BLANKET TO SOIL TEST BASED RECOMMENDATIONS FOR DIFFERENT LEVELS OF YIELD, FERTILISER USE AND CHANGE IN FERTILISER USE

Particulars (1)	Base level* Low (2)	Medium (3)	High (4)	All (5)
Base yield*	Change in yield (kg/ha)†			
Mean	218.7	121.0	188.6	171.9
No. of observations	15	26	37	78
Standard deviation	143.4	246.3	169.8	-
Base NPK (kg/ha)**				
Mean	163.3	152.8	253.0	171.9
No. of observations	18	47	13	78
Standard deviation	258.8	185.3	104.0	
Change in NPK (kg/ha)***				
Mean	85.0	210.7	223.4	171.9
No. of observations	27	22	29	78
Standard deviation	141.6	176.7	229.0	

† Change indicates difference in yield on plot A over B in ABC trials for wheat in Gujarat. Base refers to plot B.
* Criteria for distribution of base yield among low, medium and high is up to 2,500 kg/ha, 2,500 to 3,500 kg/ha and more than 3,500 kg/ha respectively.
** Criteria for distribution of base NPK use among low, medium and high is respectively up to 170 kg/ha, 170 to 200 kg/ha and more than 200 kg per ha.
*** Criteria for distribution of change in NPK due to movement from B to A among low, medium, and high is respectively negative, up to 30 kg/ha and more than 30 kg/ha.

TABLE V. INCREMENTAL YIELD ACCRUING DUE TO CHANGE IN N-P RATIO FOR DIFFERENT LEVELS OF CHANGES IN NPK FOR WHEAT

Particulars (1)	Change in NPK* Negative (2)	Up to 30 kg (3)	Over 30 kg (4)	All (5)
	Change in yield (kg/ha)			
N-P ratio changed				
Mean	71	272*	224	173
No. of observations	21	9	25	55
Standard deviation	155	162	243	
N-P ratio not changed				
Mean	133	168	217	167
No. of observations	6	13	4	23
Standard deviation	70	174	110	
All				
Mean	85	211	223	172
No. of observations	27	22	29	78

* Significantly different at 5 per cent from the case when N:P is not changed.

III

ADOPTION OF SOIL TEST RECOMMENDATIONS BY FARMERS

The economic gains indicated by the ABC trials should ideally imply widespread adoption of the soil test based recommendations in tune with the crop sequence developed above. To what extent the empirical reality confirms the expected pattern? This question has been examined here with the help of survey data covering 432 farmers provided with soil testing services and located across five soil-crop zones mainly under irrigated conditions in Gujarat.[9] Out of 432 farmers, 102 had not received the soil test based recommendations before sowing, hence they were excluded from the analysis.

Farmers' fertiliser use could be compared to the (*a*) recommended level and (*b*) balance of nutrients separately as well as jointly. About 42 per cent of the cultivators had attained the recommended level irrespective of the N-P balance, whereas 45 per cent of the cultivators had attained recommended balance irrespective of the level of nutrients. But a farmer can be considered as a 'proper' adopter only if both the recommended rates and the N-P balance are simultaneously followed. Nevertheless, recommendations should be considered as a range rather than a point. This flexibility is necessary to accommodate the differences in the soil type and other field realities. If the soil test based estimates of the available nutrients in the soil are linked to the production function of the same location, adoption is defined as a situation where the cultivator follows exactly what is recommended in the soil test report. However, when the recommendations are based on the production realities of research farms, uncertainty creeps in due to both locational differences and differences in farm practices. Moreover, the soil test based recommendations are generated for a range rather than an exact value or level of soil nutrients and at the margin this alone can create a variation of about 15 per cent in the recommendation.[10]

Thus in view of the fact that the soil test based recommendations are only an approximation and not an exact optimum quantity, a difference of ± 20 per cent between the actual use and the recommended N, P and K was considered as a permissible range for identifying an adopter. Using three classes of total NPK level (proper, lower and higher than recommended) and three classes for N-P balance (proper, in favour of N, and in favour of P), nine combinations were worked out for categorising a fertiliser user. However, for analytical convenience the nine combinations were merged into four categories, *viz.*, (*i*) 'proper' level and balance; (*ii*) 'proper' level but improper balance; (*iii*) higher level, irrespective of balance; and (*iv*) lower level, irrespective of balance.

Extent of Adoption

Table VI gives the distribution of farmers across the four adoption categories. Of the total 330 farmers, 22 per cent were in the group of 'proper' use both in terms of level and balance of nutrients, hence were considered as adopters. Among the non-adopters, a very large proportion (57 per cent) of farmers had already attained the level which is either proper (with 20 per cent of farmers in category II) or higher (with 37 per cent in category III) than what was recommended irrespective of the N-P balance. For them, graduating to the status of the adopters would require adjustments without any additional financial burden. Only 21 per cent of the farmers belonged to the category of low users for whom adoption would imply serious financial burden.

The pattern of adoption, however, varied across crops. The crops having higher than the average 'proper' adoption rate were wheat, bajra and tobacco whereas cotton, sugarcane, maize and castor had nearly average rate of 'proper' adoption. The crops with low 'proper' adoption qualities were pulses, groundnut and paddy.

While low use of fertilisers was not very prominent (21 per cent), its incidence across crops was rather surprising; the incidence of low use was higher in the crops like wheat (36 per cent) and cotton (32 per cent) which are generally believed to be fertilised at high rates.

Compared to this, the incidence of lower use is not so frequent in the less preferred crops like maize, pulses and castor, where the major deficiency was improper balance rather than low level of nutrient use.

TABLE VI. ADOPTION OF SOIL TEST BASED RECOMMENDATIONS BY CULTIVATORS* FOR DIFFERENT CROPS

Crops (1)	Soil test adoption category** I (2)	II (3)	III (4)	IV (5)	All (6)
			Percentage*		
Paddy (*kharif*)	16	27	40	18	100 (43)
Bajra	29	25	25	21	100 (24)
Maize	21	42	26	11	100 (19)
Wheat	33	29	-	38	100 (21)
Pulses	11	33	33	22	100 (9)
Groundnut	13	5	70	11	100 (37)
Castor	20	40	20	20	100 (10)
Cotton	23	26	19	32	100 (73)
Tobacco	25	3	54	18	100 (65)
Sugarcane	21	16	58	5	100 (19)
All	22	20	37	21	100 (330)

* For 330 farmers who received their soil test report before sowing. Percentage of farmers growing crop in each category and having received soil test recommendations before sowing.

** I = Both level and ratio are 'proper'.
II = NPK level is 'proper' but ratio is unbalanced.
III = NPK is higher than recommended.
IV = NPK is lower than recommended.

Figures in parentheses are number of farmers growing a crop.

The crops with higher incidence of excess use were not only irrigation intensive crops like sugarcane and tobacco but also unirrigated groundnut. Although, excess users (*i.e.*, category III) consisted of both balanced and unbalanced N-P ratio, the problem of higher but unbalanced use was unlikely in the case of tobacco and groundnut. This is because a single product is recommended and being used for these two crops, Diammonium Phosphate (DAP) for groundnut and urea or Ammonium Sulphate (AS) in the case of tobacco.

Comparison of Actual and Expected Adoption

The above pattern compared reasonably well with the expected pattern of the adoption of soil test based recommendations emerging from the analysis of ABC trials data. For eight comparable crops, the actual adoption of level of fertiliser use (*i.e.*, category I + II) was in close conformity with the expected pattern in the case of paddy, tobacco, groundnut and bajra. In tobacco, groundnut and paddy the incidence of adoption was lower than the average (except for paddy where it is near the average) but excess use is much more prevalent. Bajra was characterised by high rate of adoption but low proportion of excess users, as was expected.

For wheat, cotton, maize and castor the expected pattern was low adoption with higher proportion of low users. Against this, the actual scenario was somewhat different. Instead of low, the actual adoption was higher than the average in all the four crops. However, with respect to the expected high proportion of low users, the actual pattern did match in the case of wheat and cotton. Thus wheat and cotton could be treated as partially confirming whereas castor and maize as non-confirming crops.

Apart from the above deviations, what was also surprising was the overall low incidence of 'proper' adoption in all the crops. This adoption gap should be an outcome of the farmers' perception which did not match the expected gains of adopting the recommendations.

The Rationale

What circumstances would lead to a mismatch between the expected and the actual yield response? While we have not probed into this question in detail, farmers' own rationale for non-adoption may give some clues for identifying the forces which lead to non-adoption.

The two most important reasons given by the farmers whose total NPK use differed from the soil test based recommendations were: (*i*) The yield response from changing NPK level to soil test based recommendations was perceived to be highly uncertain. (*ii*) These recommendations did not take due account of the farmers' resource base, farm practices and management skills, and hence were not found appropriate.[11]

At this stage when perceptions about yield response is being discussed, the farmers' understanding about the N-P interaction and its effect on yield also becomes important. Not only were the farmers not sure of the yield response as a result of adjustments in nutrient balance, but a large proportion of the farmers did not even understand the complementary role phosphate played along with nitrogen in improving the water use efficiency.

Thus non-adoption emerged mainly due to inappropriate services (Sah and Shah, 1990),. leading to a yield perception which is not so encouraging. The major limitations were found to be (*a*) low emphasis on the farm practices like placement of fertiliser, weeding, seed rate, use of farmyard manure, number of irrigations, etc., in the extension messages; (*b*) recommendations not adjusted to the constraints faced by the farmers; and (*c*) communicating fertiliser nutrient-yield dynamics mainly through discussions and rarely through on-farm experiments. As a result, the demand for these services has remained latent; providing these services has become an end in itself.

There are two important ways by which these limitations could be overcome. (*a*) Many more ABC trials should be conducted under varying farm conditions. (*b*) the extension interaction should be more field-based and the extension workers should be trained for making proper adjustments in the recommendations to suit the farmers' need. Since the first solution involves additional financial resources, it may not be feasible in the short run, hence greater emphasis should be given to the second alternative. Unless soil test based recommendations are effectively conveyed as a full package and made suitable to the farm conditions, farmers will not be convinced of the potential gains and the adoption will remain constrained.

IV

SUMMING UP

The ABC trials did provide evidences of substantial economic gains by adopting soil test based recommendations. This was true even on the farms where fertiliser use as well as crop yields were quite high. But the way the ABC trials were conducted, the overwhelming message conveyed was that of 'more' rather than 'efficient' use of fertiliser.

The foregoing analysis tried to explain the farmers' adoption behaviour considering size and certainty of incremental returns as the guiding force. But the farmers' apprehension about appropriateness of the soil test based recommendations, and thus their perception about incremental gains seems to play a crucial role. It appears quite likely that farmers with 'proper' fertiliser use may perceive substantial incremental gains by increasing the use still further. If this is so, the present 'proper' status of fertiliser has to be seen as only incidental; the farmers are likely to change it in accordance with their own response perceptions. Thus in order to get a comprehensive understanding of the farmers' adoption behaviour in a dynamic context, it is necessary to evolve an alternative framework which could take into account the forces influencing the farmers' perception, in addition to the forces already considered in the present analysis.

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NOTES

1. The annual growth of foodgrains production between 1964-65 and 1970-71 was about 18 per cent higher than between 1949-50 and 1960-61. This jump in production after the introduction of HYVs has been achieved due to increase in productivity. See Mellor (1976, pp. 48-49).

2. The results of these experiments were used by Hopper to develop 'yardsticks' for fertiliser, see Hopper (1965). The response functions developed from these trials were used by Desai to explain why fertiliser use varied among different crops. See Desai (1971).

3. Nutrient losses through leaching, volatilisation, run-off and locking of nutrient in soil deprive their availability to plants. See Tandon (1974 *a*, 1974 *b*, 1990).

4. The soil test results are primarily used for generating blanket (or average) recommendations. For this, soil samples are collected from different locations in a taluka. Based on the available soil nutrients in these samples pooled over five years, average NPK status is derived for each taluka.

5. A detailed analysis of the supply mechanism has been done in the larger study (Sah and Shah, 1990). It addresses the issues like appropriateness of the recommendations as well as their dissemination in terms of time, content and language.

6. The phenomenon of blanket recommendations being often lower than the soil test based recommendations is borne out of the procedure adopted for generating (average) blanket recommendation which assigns more than proportionate weight to the soil samples requiring low supplementary nutrients. For details, see Muhr *et al.* (1965).

7. Soil test based recommendations (A) were found to be higher than the blanket recommendations (B) in the case of 54 trials, most of them were in groundnut, wheat and maize. Higher net returns in B over A were found in 26 trials; almost all (*i.e.*, 25) in the case of wheat.

8. The yield impact of farm practices was examined in the larger study (Sah and Shah, 1990) which indicated that improved farm practices have significant positive influence on yield. This would imply that a part of the yield variation across plots even on a location could be explained through varying farm practices.

9. This is a purposive sample for understanding the behaviour of farmers who have received the result of soil test reports. In doing so, a list of 1,388 farmers whose soils were tested was obtained from laboratories in selected zones. The first 432 farmers who have received the results were selected for the study. The reference year of the study is 1988-89. For details about the sample design, see Sah and Shah (1990).

10. For example, soils with organic carbon (OC) percentage of 0.25 and 0.26 fall in the two different ranges, *i.e.*, (*i*) up to 0.25 and (*ii*) between 0.26 and 0.4; since the two ranges imply different levels of N content in the soil, the recommendations also vary in these two cases. For irrigated HYV wheat, the N recommendations in the first case is 195 kg. per hectare and in the second case is 170 kg. per hectare. Thus at margin there is about 15 per cent variation in the recommended N due to 0.01 per cent difference in the OC content. Recognising that the OC values are generated for a range, the recommended nutrient quantities should also be considered as a range rather than a point recommendation, the form in which they are presently made available.

11. Not only that some farmers found these recommendations unsuitable but there are also certain methodological issues which would raise doubts about their appropriateness (Sah and Shah, 1990). For instance, the agricultural university generates these recommendations to be applicable for medium status soils. In fact, the experiments are not necessarily conducted on medium status soils. Secondly, for low and medium status soils, these recommendations are adjusted upwards and downwards by 30 to 50 per cent respectively. The categorisation of soil status adopted by the university

is too broad, hence may not give accurate estimate of required fertilisers for individual farms. Lastly, the recommended quantities are subject to adoption of a set of improved farm practices. To the extent these farm practices are not followed on farmers' fields, the optimum requirement might well differ from what is recommended.

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