Package of Practices Approach in Adoption of High-Yielding Varieties

An Appraisal

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Much of, the research and extension effort in India in connection with the development and release of high-yielding varieties since the mid-1960s has revolved around the concept of a 'package of practices'. The implication which farmers and others seem to derive from this approach is that unless they include all parts of the input package at their 'recommended' levels, HYV technology will not be of any benefit.

This paper compares the likely benefits from the adoption of three 'different packages of technology, using extensive crop-fertiliser response data froma number of sources, most of which are derived from experiments conducted in the farmers' fields.

On the basis of the admittedly limited evidence presented here, there would seem to be a case for closer examination of the current emphasis in research and extension on the 'package of practices' approach. If the aim is increased levels of adoption of new technologies in agriculture, the analysis here suggests that parts of the package can have a significant contribution to make.

I

Introduction

MUCH of the research and extension effort in India in connection with the development and release of high-yielding varieties (HYVs) since the mid-1960s has revolved around the concept of a 'package of practices'. Fanners have generally been extolled to adopt the HYVs of crops like paddy, wheat, bajra, jowar and maize along with vastly increased amounts of fertilisers, pesticides, insecticides, etc, to gain maximum benefit from the new technology. The implication which fanners and others seem to derive from the literature on HYVs is that unless they include all parts of the input package at their 'recommended' levels, HYV technology will not be of any benefit.

According to the Programme Evaluation Organisation of the Planning Commission {15, pp 159-160] the proportions of Indian farmers adopting all four recommended practices in the 1908-69 rabi season was 9.43, 16.62 and 55.84 per cent for wheat, paddy and jowar, respectively.[1] One might have expected those percentages to be in the reverse order, with wheat, the most successful green revolution crop, having a higher proportion of farmers adopting all four practices. It has been suggested by B A Krantz (private communication) that three of the chosen recommended practices for wheat in the Planning Commission's study, namely seed treatment, insect control and inter-culture, were generally not required in practice. This may help explain the unexpected results for wheat. The percentage of participants using some type of fertiliser in the high-yielding variety programme was 77, 90 and 71 per cent for wheat, paddy and jowar, respectively [15, pp 161-162]. The proportions adopting the recommended levels of chemical fertilisers were 54, 61 and 64 per cent in the three crops, respectively [15, p 30]. In another study, Gowda and Jalihal [6] found that no paddy farmer in the IADP district of Mandya in Karnataka adopted all eight recommended practices. Almost two-thirds of them adopted only three or less.

In the well-known rural development project of Puebla in Mexico which was implemented from 1967 to 1974 with the primary aim of increasing maize production, a pattern of adoption similar to that in India was evident. Three recommended practices: (i) increased nitrogen applications, (ii) increased P_2O_5 applications and (iii) increased plant densities, were promoted by an extensive extension effort in the project area, together with institutional credit, crop insurance, input supplies,, etc. Despite these favourable circumstances, according to Cummings Jr [2, p 24] "... farmers themselves experimented with recommendations, often adopting them in stages rather than as a complete package .. . ". In a random sample survey of 200 farmers in the Puebla Project in 1972 only 10 per cent had adopted all three practices at close to recommended levels. About half the sample had adopted all of the practices but with at least one or two of them at levels significantly below the recommendations. Forty *per* cent of farmers did not adopt any of the practices.

The fact that there are such differences between the numbers of participants in the high-yielding varieties programme who adopt parts versus the complete package of recommended practices, particularly with wheat and paddy, suggests that the 'package' approach may not be entirely appropriate in all instances. How much it has been responsible for non-adoption of the simplest part of the package — namely, just a change to the HYV of seed — can only be guessed at. If this simple change is itself profitable, then the opportunities foregone in extending the complete package approach might be significant. It is possible that many farmers are deterred from just trying the new variety while still using their other traditional practices. They could be encouraged to adopt practices in a sequential manner, rather than in an all-or-nothing type of framework. Each part of the package might be looked upon by farmers as a less risky activity than the complete package in terms of what the farmer could lose if crop failure resulted. If, this were true, then this sequential approach might increase adoption of HYVs in the longer-run. The ancillary inputs in the package could be added, according to their relative profitability, and as working capital was accumulated from introductions of previous parts of the package.

In this paper we compare the likely benefits from adoption of three different packages of technology using extensive crop-fertiliser response data from a number of sources, most of whkh were derived from experiments conducted in farmers' fields. The three packages involve a change from growing the traditional local variety (LV) with zero nitrogen fertiliser to:

(A) a HYV of the crop with nitrogen fertiliser kept at zero;
(B) an increase in the quantity of nitrogen fertiliser from zero to the derived economic optimum level for the . traditional LV;
((') a HYV of the, crop and an increase in the quantity of nitrogen fertiliser from zero to the derived economic optimum level for the HYV.

Practice A might be looked upon as the simplest change in technology and C the most complex of the three, involving also the largest increase in costs. Practice B might be regarded as an intermediate technology. We want to examine whether farmers have to change all other input levels (in this case only fertiliser, due to data limitations) in order to reap the advantages of HYV's.

II

Methodology

Data from crop-nitrogen response studies conducted on wheat, paddy, jowar, bajra and maize by Kanwar [9], Krishnamoorthy *et al* [10, Table 4], Krishnaswamy and Patel [11, pp 76, 87], Mahendra Singh *et al* [12, p 308], Murthy [13, p 151], Rabeja *et al* [16],, Rao [17], Saxena and Sirohi [18, p 125] and Shah [19, p 164] were used to calculate the additional costs, additional yields, and additional net returns from the above three packages A, B and C. We recognise the importance of fertiliser mixtures in many situations, rather than a single nutrient like nitrogen. The single nutrient response data are used only for convenience.

To examine the economics of the above three packages we assume the response function for a LV to nitrogen (N) to be:

TABLE 1 : INCREMENTAL PROFITS FROM ADOPTION OF PACKAGE OF PRACTICES VERSUS ADOPTION OF SINGLE PRACTICE

Practice	Unit	Wheat		Paddy	Maize		Jowar				Bajra
Data Source		a	b	a	a	c	a	d	e	f	a
No of trials/centres		NA	13 Centres (1964-65)	N A	N A	17 trials (1961-63)	N A	25 (1965-70)	8 locations (1965)	8 locations (1970-71)	N A
Irrigated or Unirrigated		Irrigated	Irrigated	Irrigated	Irrigated	N A	Irrigated	Unirrigated	NA	NA	Irrigated
Varieties compared		Kalyana sona vs C 306	Sonara 63 vs NP varieties	IR 8 vs NSJ 98	Hybrid vs Local	Hybrid vs Local	Hybrid vs Local	CSHI vs Local	CSHI vs Local	CSHI vs Local	HB I vs. T. 55
(A) Nil Nitrogen (N) fertiliser but change from local to MV :											
i) Additional cost	Rs/Ha	168	168	88	15	15	100	100	100	100	28
ii) Additional yield	Kg/Ha	227	213	428	422	352	1100	985	460	1050	670
iii) Additional profits	Rs/Ha	127	109	99.2	491	407	1165	1033	429	1107	669
iv) Additional profits per additional rupee of cost	Rs/Rs	0.76	0.64	1.13	32.7	27.13	11.65	10.33	4.29	11.07	23.89
(B) Increase from nil to economic optimum N fertiliser level on LV :											
i) Additional N fertiliser	Kg/Ha	72	51	63	124	142	45	124	152	100	90
ii) Additional cost	Rs/Ha	314	222	274	540	617	196	540	663	435	392
iii) Additional yields	Kg/Ha	1742	640	624	1412	1479	320	726	837	790	530
iv) Additional profits	Rs/Ha	1951	610	381	1154	1158	126	295	299	473	159
v) Additional profit per additional rupee of cos	Rs/Rs	6.20	2.70	1.39	2.14	1.88	0.64	0.55	0.45	1.09	0.41
(C) Change from LV to MV and apply from nil to economc optimum N fertiliser :											
i) Additional N fertiliser	Kg/Ha	254	97	124	139	206	84	142	137	150	170
ii) Additional costs	Rs/Ha	1274	591	628	620	912	466	718	698	753	768
iii) Additional yield	Kg/Ha	5439	1745	2409	2458	3059	1950	3021	1989	3090	2670
iv) Additional profits	Rs/Ha	5797	1679	1441	2330	2759	1777	2756	1589	2800	2009
v) Additional profit per additional rupee of cost	Rs/Rs	4.50	2.84	2.29	3.76	3.02	3.81	3.84	2.28	3.72	2.61

Sources : (a) Kanwar (9) (b) Saxena and Sirohi (10p+125) (c) Shah (19, p 164) (d) Singh *el at* (12 pp 15-33) (e) Murthy (11 p 151) (f) Krishnamurthy *et al* (10 Table 4)

(1) $Y_{LV} = a_{LV} + b_{LV} N - c_{LV} N^2$

where Y_{LV} = total yield of the LV,

a_{LV} = yield at zero N,

b_{LV}, c_{LV} = coefficients of the linear and quadratic terms, respectively;

and that for the HYV to be:

(2) $Y_{HYV} = a_{HYV} + b_{HYV} N - c_{HYV} N^2$,

with terms as explained above for the LV.

The additional yield under practice A is given as $\triangle Y$, where:

(3) $\triangle Y = a_{HYV} - a_{LV}$.

The additional yield under practice B is found first by determining the optimal level of N by equating the first derivative of equation (1) to the ratio of the price of nitrogen (P_N) to the price of the crop (P_{LV}):

(4) $dY_{LV}/dN = b_{LV} - 2c_{LV}N^* = P_N/P_{LV}$.

The calculated optimum level of N^* in equation (4) is used in equation (1) to calculate the optimum yield Y^*_{LV} under practice B. The added yield under B is then calculated as:

(5) $\triangle Y_{LV} = Y^*_{LV} - a_{LV}$.

The added yield under practice C. is calculated in a similar fashion to that in practice B.

First, equation (6) is solved for N^{**}, the optimal level of N on the HYV:

(6) $dY_{HYV}/dN = b_{HYV} - 2c_{HYV} N^{**} = P_N/P_{HYV}$.

TABLE 2 : INCREMENTAL PROFITS FROM ADOPTION OF A PACKAGE OF PRACTICES VERSUS ADOPTION OF SINGLE PRACTICE ON WHEAT AND PADDY IN DIFFERENT REGIONS

Practice	Unit	Wheat (1967-71) Regions*					Paddy (1967-71) Regions** Kharif					Rabi Irrigated		Rabi-Unirrigated
		Northern	Indo Gangetic	Western	Central	Over all the Regions	Southern	North-eastern	Central	Northern	Over all the Regions	Southern	Over all the regions	Southern
No of trials : MV	No	552	976	458	249	2235	502	180	119	146	947	416	626	308
LV	No	116	654	539	124	1436	459	143	168	91	861	281	281	215
(A) Nil Nitrogen (N) Fertiliser but change from local to High Yielding Variety :														
i) Addl costs	Rs/ha	168	168	168	168	168	88	88	88	88	88	88	88	88
ii) Addl yields	Kg/ha	400	235	190	202	338	686	851	(—) 84	226	420	789	782	—285
iii) Addl profits	Rs/ha	352	305	79	95	271	350	629	(-)376.4	(-) 5.0	150	518	511	—608
iv) Addl profit per per addl rupee of cost	Rs/Rs	2.09	1.37	0.47	0.56	1.61	3.98	7.15	(-)4.28	(-)0.05	1.70	5.88	5.81	—6.9
(B) Increase from Nil to N60 P30 level of fertilisation on local variety :														
i) Additional fertilisers	Kg/ha	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30
ii) Addl costs	Rs/ha	395	395	395	395	395	395	395	395	395	395	395	395	395
iii) Addl yield	Kg/ha	878	743	581	1273	755	1066	1047	1327	1189	1157	922	922	738
iv) Addl profits	Rs/ha	746	571	360	1260	586	724	704	998	853	820	573	573	775
v) Addl profit per addl. rupee of cost	Rs/Rs	1.89	1.44	0.91	3.19	1.48	1.83	1.78	2.53	2.16	2.07	1.45	1.45	1.96
(C) Change from LV to MV *and* apply from nil to N60P30 level of fertilisers :														
i) Addl fertiliser	Kg/ha	N50P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30	N60P30
ii) Addl cost	Rs/ha	563	563	563	563	563	483	483	483	483	483	483	483	483
iii) Addl yield	Kg/ha	1675	1295	945	1619	1410	1963	2009	1143	1183	1305	2088	2047	511
iv) Addl profits	Rs/ha	1614	1120	665	1542	1270	1382	1425	603	641	757	1453	1462	2
v) Addl profit per addl rupee of cost	Rs/Rs	2.86	1.99	1.18	2.73	2.25	2.86	2.95	1.25	1.33	1.57	3.01	3.03	0.005

* Consists of the following states : 1. Northern (Delhi, Haryana, Punjab), 2. Indo-Gangetic (Bihar, U P, W Bengal), 3. Western (Gujarat, Maharashtra, Rajasthan), 4. Central (Madhya Pradesh).

**Southern (Andhra Pradesh, Mysore, Tamil Nadu); North-Eastern (Bihar, W Bengal); Central (Madhya Pradesh); Northern (Haryana, Uttar Pradesh); Eastern (Orissa).

Sources : Simple fertiliser trials on cultivators' fields 1967-71 as given in Rao (17 pp 29-30.)

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Then N^{**} is substituted in equation (2) to derive Y^{**}_{HYV} and then the change in yield $(\triangle Y_{HYV})$ from the change involved in practice C is calculated as:

(7) $\triangle Y_{HYV} = Y^{**}_{HYV} - a_{LV}$

Additional returns are calculated by applying the product prices in the appendix to the above yield data. Additional costs for HYV seeds and fertilisers are also shown in (he appendix. Prices used were those reigning in 1974. Additional labour costs were not included for applying extra fertiliser as this can be supplied by family labour. Additional labour costs for harvesting and threshing were also not included. No significant differences could be found between these latter costs per hectare on forms with different yields in a regression analysis performed on some paddy production data kindly supplied by Suryanarayana of Andhra Pradesh Agricultural University. Similarly, no significant deference in the labour requirement for harvesting and threshing local and hybrid jowar was reported by Vcnkataram and Ramanna [21], though there was a significant difference in yields. Desai and Mohan [4] found that in the Kaira District of Gujarat in 1967-08 hybrid bajra required that in the Kaira District of Gujarat about 14 man-days per hectare more to harvest than deshi bajra. Yield of the hybrids was 85 per cent more than that of the deshi varieties. Basu [1, pp 6-11] found for irrigated wheat, maize and bajra in Haryana and Bihar that the HYVs required an additional five man-days per hectare, for harvesting and threshing compared to LVs.

On the basis of the lack of a clear picture of the added labour requirements for HYVs from the above sludies, it was decided not to allow for additional labour costs. The magnitude of any such costs would also be small and would in no way effect the conclusions drawn from the analyses later in the paper.

It is further assumed that all other management factors except levels of fertilisers, were similar between the LVs and the HYVs. The various sources from which the fertiliser response datawere taken did not indicate anything to the contrary.

Unfortunately, measures of the statistical significance of differential yield responses of LVs and HYVs to fertilisers were not available. This was a deficiency in the data, although most of the response curves were derived over many locations, so hopefully they represent the differences one would observe in practice.

We realise the data available to illustrate the points being made in the paper may not be ideal, but sufficient multi-factor experiments related to the whole package of practices for various locations are not available. As a consequence, the specific empirical results presented should not in anyway be taken as recommendations as to the use of varieties or fertilisers in the regions from from where the data came. They arc purely illustrative.

TABLE 3 : ADDITION IN COSTS, YIELDS AND RETURNS PER HECTARE FROM CHANGE FROM ONE VARIETY TO ANOTHER AND ADOPTING DIFFERENT LEVELS OF PACKAGE OF PRACTICES IN JOWAR IN BELLARY DISTRICT OF KARNATAKA, KHARIF, 1972

Item	Unit	Shift from					
		Local to Improved Local Variety	Local to Hybrid (non-programme)	Local to Hybrid (Programme)	Improved Local to Hybrid (non-programme)	Improved Local to Hybrid (Programme)	Hybrid (non programme) to Hybrid (Programme)*
Seed	Rs/ha	0	32.5	42.5	32.5	42.5	10.0
Farmyard Manure	,,	5.0	12.5	20.0	7.5	15.0	7.5
Fertiliser	,,	15.0	55.0	272.5	40.0	257.5	217.5
Pesticides	,,	0	2.5	15.0	2.5	15.0	12.5
Human Labour	,,	—5.0	12.5	10.0	17.5	15.0	—2.5
Bullock Labour	,,	—7.5	2.5	7.5	10.0	15.0	5.0
Other Variable Costs	,,	2.5	2.5	10.0	0	7.5	7.5
Total Variable Costs	,,	10.0	120.0	377.5	110.0	367.5	257.5
Additional Yields	Kg/ha	165	440	705	275	540	265
Additional Profits	Rs/ha	147.5	222.5	162.5	75	15	—60
Additional Profits per rupee of additional cost	Rs/Rs	14.7	1.85	0.43	0.68	0.04	—0.23

*Hybrid (Programme) means the cultivation of the crop under the full package of practices as recommended by the action programme working groups under the supervision of the lead bank agricultural officers. Hybrid (non-programme) means cultivation of the crop as done by the cultivator. Each comparison in the table does not necessarily represent the treatments being grown side-by-side on the same farm, although the majority were.

Source : Krishnaswamy and Patel (11, p 76, Table 4.1, p 87, Table 4.7)

III

Results and Discussion

The results of these analyses are presented in Tables 1-3. In Table 1 in the case of wheat, a simple shift from a LV to a HYV (practice A) without applying nitrogen fertilisers resulted in marginal additional profits of around Rs 100/ha, But a combination of HYV seed and the economically optimum level of nitrogen fertiliser (practice C) resulted in substantial additional profits. Although in per hectare terms the additional profit from practice C was about three times as large as the additional profits from applying the optimum level of nitogen fertilizer to LVs (practice B), a comparison of additional gains per rupee of additional cost shows that practice B was more profitable than C for Kalyanasona and about the same for Sonara 63.

Slightly different results emerge from a regional analysis of the performance of HYVs and LVs in hundreds of simple fertiliser trials conducted in farmers' fields in 1967-71, as reported by Rao [17], and shown in Table 2.2 The total additional profits per hectare for wheat were always greater for practice C, followed by B, then A in all four regions. This was also true using the additional profits per rupee of additional cost criteria in the case of the Indo-Gangetic and Western Regions. In the Northern Region, practice C rated first using this criterion, followed by A then B. In the Central Region the order was B, C, A.

Hence, for wheat it seems clear that, while the package of HYV seed plus optimum doses of nitrogen fertilisers generates the largest additions to yields and profits of the three practices examined, it also involves an extremely large additional cost to achieve this. In some instances it may be more desirable to apply fertilisers to LVs.[3] In situations where limited

Appendix

Prices Used in the Analyses (1974)

Price of nitrogen		4.355 Per/ Kg
Price of produce :		Rs/Q
White jowar		115.00
Bajra		104.00
Maize		120.00
Dwarf rice		95.00
Local rice		105.00
Wheat		130.00
Price of seeds :		Rs/Kg
Wheat	HYV	3.75
	Local	2.30
Paddy	HYV	2.20
	Local	1.00
Jowar	Hybrid	12.00
	Local	2.00
Bajra	Hybrid	9.00
	Local	2.00
Maize	Hybrid	4.00
	Local	3.00
Seed rates :		Kg/ha
Wheat	Local	90
	HYV	100
Paddy	Local	22
	HYV	50
Jowar	Local, HYV	10
Bajra	Local, HYV	4
Maize	Local, HYV	15

cash resources are available, as in the case of small farmers, a profitable yet low cost (comparatively) practice involving just a change to HYV seed with zero fertiliser might be recommended initially. With the additional profits generated from this, in subsequent years they may invest in fertilisers and other complementary inputs. It may not always be true, as Kanwar *et al* [8, 9] and others state, that fertiliser application is more profitable on HYVs than LVs when criteria other than profits per hectare are considered.

For paddy, Table 1 shows that a switch to HYV seed gives about the same additional profits per hectare as in the case of wheat. The package of practices involved in C for paddy is extremely profitable at Rs 1441 per hectare, compared to Rs 381 for practice B. In terms of profits per rupee invested in the practices, Table 1 suggests that package C is the best, followed by B then A.[4] Table 2 shows somewhat different results. In the Southern and North Eastern paddy regions, a simple switch to HYV seed itself will be highly profitable, particularly in the rabi. Of course additional profits .per hectare are greatest for practice C in these regions. However, on an additional profit per rupee of additional cost basis, practice A is well ahead of both C and B. For the Central and Northern Regions in the kharif, a switch to HYVs of paddy without fertilisers is unprofitable. Applying fertilisers to LVs is also more profitable in these regions than applying it to HYVs, whether using profits per hectare or profits per rupee of cost as the criterion.[5] These data no doubt help to explain the varying levels of adoption of HYVs of paddy in different states and their popularity in the rabi season.

In the case of jowar as shown in Table 1, a simple switch to HYV seed is highly profitable, with the marginal returns per unit of cost around ten and profits per hectare around Rs 1,000 in most cases. Profits per hectare arc greater if extra fertilizer is applied to HYV jowar, but the profits per rupee of cost are much lower than practice A.° Applying fertiliser to LVs of jowar is not nearly as profitable as practices A or C.

Applying optimum levels of N fertiliser to HYVs of maize generates extra profits per hectare of more than Rs 2,000. This is five times more profitable per hectare than just changing to HYV seed, but the latter practice is ten times more profitable per rupee of additional cost. Applying optimum levels of N fertiliser to LVs of maize is also very profitable at some Rs 1,100 per hectare, although it rates well below practice C on a profit per rupee of cost basis.[7]

Applying optimum N fertiliser levels to HYV bajra is also highly profitable, as was shown for jowar and maize, at around Rs 2,000 per hectare. The simple change to HYV seed with no fertiliser generates only about Rs 700 of added profits per hectare. In terms of returns on additional costs though, he latter practice is ten times better than the former.[8] Fertiliser applications to LVs of bajra are not very profitable by any criterion.

The question arises as to why the adoption rates for HYV maize and HYV jowar have not been as great as they have been for wheat, bajra and paddy in the light of the apparent large potential profits to be made from just trying the new seeds.[9] No doubt tho fact that wheat is generally irrigated has a lot to do with its high adoption rate. Irrigation apparently has the effect of reducing the risk and enhancing the profitability of HYVs and of the fertiliser applications on them. This is not so with bajra, which is largely unirrigated.

One might be led to conclude that the data in Tables 1 and 2 do not really express the relative riskiness of adopting new practices. For example, Kanwar *et al* [8] showed quite clearly by individually analysing the hundreds of experiments in farmers' fields, which Rao [17] also used, that in about three out of every four fertiliser experiments on HYV jowar, the profits from fertiliser applications were negative. In HYV maize less than one in ten gave negative profits in most areas and in HYV bajra the figures were about one in two in unirrigated experiments and one in four in those irrigated. HYV jowar adoption may hence be insignificant partly due to the inherent riskiness of the new HYVs, even at low levels of fertilisers. The additional returns per rupee of additional investment in HYV seed for jowar is also much lower than for HYV maize and bajra from Table 1. This could be another factor in explaining poor adoption of HYV jowar. Also, one package deal for different environmental situations, particularly for rainfed areas, is undesirable. Many practices are location specific. Data from the Indian Institute of Management study in the Bellary District of Mysore State in 1972-73, (Table 3) show that a shit from LVs to improved local varities of jowar with some other small input changes had a much higher pay-off per rupee of additional investment than a shift from LVs to HYVs[10]

The improved local varieties are generally still classified as 'local' when est mates are being made of the rate of adoption of high-yielding varieties.

HYV bajra may be more popular because the probability of a profitable fertiliser response is much greater than that of HYV jowar as shown by Kanwar *et al* [8].[11] But HYV maize apparently has the greatest probability of a profitable fertiliser response according to the same authors, yet its adoption percentage is about half that of HYV bajra. The explanation for this may be in the inferior consumer characteristics of the new maize varieties or in unavailability of seeds, etc, However, the latter problem would not appear to be peculiar to the HYV's

of maize alone. It has apparently been a general problem in the high yielding varieties programme.[12]

IV
Conclusion

It would seem that, on the basis of this admittedly rather limited amount of evidence, there is a case for closer examination of the current emphasis in research and extension on the 'package of practices' approach. If we are aiming at increased levels of adoption of new technologies to improve the well-being of both farmers and consumers, the present analysis suggests that parts of the package themselves can have a significant contribution to make.

This is not to deny the obvious advantages in complementing parts of the package with other parts which have multiplicative rather than additive effects on yields and profits. These are the 'synergistic effects' which Swaminathan speaks of [20, pp 29-301. The data presented clearly show the superior profits per hectare which can be earned by combining optimum doses of nitrogen fertilisers with a change to a HYV for all crops examined. The thrust of this paper was to indicate that significant yield and profit increases may still be generated by less radical changes in technology involving perhaps such minimum cost and minimum risk strategies as a change in the variety of seed used. Of course in some cases it may be a more economical use of limited extension resources to concentrate on the whole package in attempting to encourage adoption, rather than on parts of the package. This must be weighed up against the possible effect of this approach on non-adoption of parts of the package.

If, as seems plausible, many farmers in less developed countries are constrained by internal and/or external liquid capital rationing, then the return per unit of that limited liquid capital becomes an extremely important criterion governing decisions. Returns per hectare of land can be less relevant in making decisions under these circumstances. In most instances it is small farmers who are faced with this type of constraint.[13] In the majority of the experiments analysed in this paper the additional profits earned per unit of expenditure on a practice involving a minimal change was equal to or greater than the benefits from the more complex and much more expensive packages. It is only a guess as to how many small farmers might have adopted small portions of the package and reaped significant rewards on the way to possible complete adoption at some later time, had research and extension placed more emphasis on presentation of a 'range of input options' rather than a 'package of input practices'. It is useful to distinguish here between changes in management practices involving little if any additional cost, and changes in use of expensive inputs such as chemi cal sprays and fertilisers. Management practices of course can be included in recommendations for HYV's for virtually all farmers. When it comes to more expensive input practices, recommending options for different farmer constraint situations would seem appropriate. It is the latter which were the prime concern in this paper.

In this respect it is heartening to see the approach being taken by the International Rice Research Institute in determining the separate and combined effects of various management practices and input levels on rice yields in farmers' fields.[14] These experiments involve evaluation of recommended practices such as insect control, water management, fertilisers, weed control seed source and seedling management, compared with farmers' existing practices in a factorial experimental design. Single and interaction effects are measured and economic analyses performed to determine which practice(s) generate the highest returns. This approach is commended to all research workers as a model for emulation. The Farming Systems Research Programme at ICRISAT has recently initiated "steps in technology" experiments which follow this pattern.

Notes

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1 The four practices were seed treatment, use of chemical fertilisers, plant protection and inter-cultural operations. The percentages refer to proportions of selected farmers who participated in the high-yielding varieties programme in sit states of India. Unfortunately, important practices like reduced depth of planting and shifting to early and late irrigations were not evaluated in the quoted study. It is likely that. especially in the case of wheat, adoption of these two practices would have been high, However, they represent miminum cost changes in management, rather than large input increases.

2 The results for practices B and C in Table 2 are not strictly comparable with those in Table 1 as the fertiliser levels in Table 2 are not necessarily the economically optimal levels.

3 While not shown in Table 1, we also examined the benefits of applying 20 kgs of N per hectare to LVs, and 40 legs to HYVs of wheat, on the grounds that it is the first few units of N which give the highest benefit/cost ratio. For LVs of wheat the additional profits per rupee of cost using 20 kgs of N was about 80 per cent higher than using optimum N levels on LVs. For HYVs of wheat, 40 kgs of N gave about 20 per cent higher additional profits per rupee of cost than the optimum cost of N on HYVs.

4 Application of 20 kgs of N per hectare on LV paddy gave 70 per cent higher additional profits per rupee of cost than practice B. 40 kgs of N per hectare on HYV paddy gave 40 per cent higher additional profits per rupee of cost than practice C.

5 It should be recalled that the levels of fertilisers being compared here are not necessarily the economically optimal ones. With optimal doses applied to both LVs and HYVs the situations may be different.

6 Although the additional profits per rupee of cost from applying just 40 kgs of N per hectare to HYVs of jowar was about double that from the optimum levels of N.

7 Additional profits per rupee of cost can be doubled by applying 20 and 40 kgs of N per hectare to LVs and HYVs respectively, compared to optimum N levels.

8 Again, the additional profits per rupee of cost can be more than doubled by reducing N fertiliser levels to 20 and 40 kgs per hectare on LV and HYV bajra, respectively.

9 According to Dalrymple [3, pp 48-51], the proportion of high yielding varieties of wheat and rice sown to the total areas of the crops in 1970-71 was 32.9 and 14.7 per cent, respectively. Rao [17, p 5] indicates that the equivalent percentage for bajra, maize and jowar in 1971-72 were 15.8, 8.7 and 5.4 respectively.

10 In this study the values of by-products were also included. This was not done in Tables 1 and 2 as the data were not available.

11 Furthermore, it may be more critical in the case to HYV jowar to follow all other practices such as seed treatment, plant protection, inter-cultivation etc, than in other crops. The fact that more than 50

per cent of participants in the 'package programme investigation by the Programme Evaluation Organization of the Planning Commission (15, pp 159-168] adopted all four recommended practices, compared with about 9 and 17 per cent in wheat and paddy respectively, might suggest this.

12 See for example Programme Evaluation Organisation, Planning Commission [14, p 38].

13 Indeed, even countries as a whole may find capital to be a more binding constraint than crop land, and in order to maximise crop production for the country (if that is the goal) by the use of HYVs it may be more relevant to consider yield per unit capital than of land in making policy decisions to achieve this. If capital and/or credit are not limiting then yield or returns per unit of land or other binding resources becomes relevant.

14 See the papers by Gomez *et al* [5] and the International Rice Research Institute {7]. Similar work on maize is being done by E Baker and his colleagues at the Institute of Agricultural Research at Samaru in Northern Nigeria (A H Kassam, personal communication).

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