FERTILIZER-USE PATTERN AND PROBLEMS IN WHEAT PRODUCTION IN PUNJAB, INDIA

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The Punjab occupies a geographical area of 5.04 million hectares, out of which 4.28 million hectares are arable. This constitutes about 2.3 percent of cultivable area in the Republic of India. The soil and climatic conditions of the province are such that the land can raise crops all the year around. The crops sown here can be divided into two groups: winter season crops and summer season crops. Wheat, rice, barley, corn, jowar (Sorghum vulgare) and bajra (Pennisetum typhiodes) are the major cereal crops; pea-nut, sesamum, rape and mustard and linseed (Linum usitatissimum) the oil seed crops; sugarcane, potato, and cotton the cash crops. The Punjab is considered the wheat granary of India. The trends of wheat production in the province in relation to the country on the whole for the last 5 years are shown in Table 1.

Table 1. Trends of wheat production in relation to area under wheat in Punjab, India.

Year	Punjab	India	% in Punjab over India basis
	Production (x000 tonnes)		
1968-69	4,491	18,651	24.1
1969-70	4,865	20,093	
1970-71	5,145	23,832	21.6
1971-72	5,618	26,477	21.2
1972-73	5,368	24,923	21.5
	Area (x000 hectares)		
1968-69	2,063	15,958	12.9
1969-70	2,167	16,626	
1970-71	2,300	18,241	12.6
1971-72	2,335	19,163	12.2
1972-73	2,401	19,881	12.1

Source: Statistical Abstracts of Punjab 1968 to 1973.

With the adoption of advanced technology in agriculture like the introduction of high yielding and dwarf varieties of cereals, use of chemical fertilizers, sound agronomic practices and timely pest and disease control measures, the yield of wheat has markedly increased in the Punjab and the province now produces the highest average wheat yield in the country. The data in Table 2 gives the yield of wheat obtained in the Punjab as compared to other provinces in the country.

Table 2. Yield estimates of wheat (in kg/ha) in Punjab in relation to different provinces in India.

Assam	Bihar	Gujarat	Haryana	H.P.	J&K	Karnatka	M.P.
1432	1250	1475	1755	1160	935	366	693

Maharashtra	Orissa	Rajasthan	U.P.	W. Bengal	Punjab
360	1949	1253	1200	1765	2233

India
1254

Fertilizer-use Trends in the Punjab

Fertilizers constitute an important input for increasing crop yields and are essential under intensive cropping systems. The contribution of fertilizers in increasing agricultural production has been well documented. A comparative study made on factors influencing production for the 1956-61 period indicated that fertilizers contributed to increasing agricultural production to the extent of 45 percent, while other factors like irrigation, improved seed, double cropping, and land reclamation measures contributed 27, 13, 10 and 5 percent respectively (Datta, 1967)*. In the Punjab, fertilizers have played a key role in the realization of the "Green revolution" Today increasing consideration is being given to rebuilding native soil fertility, in addition to supplying the immediate requirements of the crops being grown. The trends in the consumption of fertilizers in the Punjab since 1960-61 are shown in Table 3. It is evident that the fertilizer consumption has increased rather rapidly. Actually, during the period of expanding usage of fertilizers in the state, the demand has always exceeded the supply.

Table 3. Trends in nutrient (N, P_2O_5 and K_2O) consumption in Punjab since 1960-61 (tonnes).

Year	N	P_2O_5	K_2O	Total
1960-61	2,681	134		2,815
1961-62	9,161	548		9,709
1962-63	16,560	1,124		17,684
1963-64	25,926	1,947		27,873
1964-65	41,617	3,230		44,847
1965-66	42,862	3,414	459	46,735
1966-67	46,381	4,554	741	51,676
1967-68	89,460	15,072	3,477	1,08,009
1968-69	1,35,873	31,106	10,767	1,77,746
1969-70	1,46,800	21,040	6,360	1,74,200
1970-71	1,74,766	31,400	7,008	2,13,174
1971-72	2,24,379	52,890	11,938	2,89,207
1972-73	2,17,662	65,119	10,167	3,00,948
1973-74	2,24,566	69,856	21,378	3,15,800

Source: Directorate of Agriculture, Punjab, Chandigarh.

* Datta, N.P. (1967). J. Indian Soc. Soil Sci. 15:192.

Table 4 shows the consumption of nutrients per unit of agricultural land in the Punjab in comparison with other selected states in India.

Table 4. Consumption of nutrients in kg/ha of agricultural land in selected provinces in India.

State	Consumption of $N + P_2O_5 + K_2$ (kg/ha of Agri. land)						
	1962-63	1965-66	1968-69	1970-71	1971-72	1972-73	1973-74
Andhra Pradesh	8.60	8.08	21.45	19.34	20.28	18.79	18.67
Gujarat		5.10	8.54	14.37	16.20	15.89	19.11
Kerala	9.38	12.63	24.20	18.09	21.08	24.42	26.94
Maharashtra		4.20	6.18	9.51	11.48	9.53	10.92
Karnataka	3.06	3.83	8.47	12.39	13.02	15.85	15.20
U.P.	2.21	4.29	14.74	17.07	20.12	21.85	16.51
Tamil Nadu	10.07	13.40	22.70	34.50	44.99	42.17	42.46
Punjab	3.37	4.99	34.24	40.24	52.64	58.61	69.28
All India	3.28	4.60	9.58	12.30	14.53	14.94	15.06

Source: Fertilizer statistics (1962 to 1974), F.A.I., New Delhi.

It is seen that the nutrient consumption in the Punjab in the early sixties was among the lowest, but with passage of time, the consumption has increased so fast that currently the fertilizer-use here is the highest in the country. With the intensive type of agriculture being followed in the state, there is a great scope for further expansion in the fertilizer use. The various fertilizer materials that have been in use in the province are detailed in Table 5.

Table 5. Trends in use of various types of fertilizers in Punjab during different years.

Fertilizer	Amount of distribution (tonnes)					
	1962-63	1965-66	1968-69	1970-71	1971-72	1972-73
Ammonium sulphate	20,750	46,169	1,16,938	22,314	3,888	6,010
Urea		74	96,338	1,52,072	2,10,638	2,51,340
Ammonium sulphate nitrate			2,791	278	257	46
Calcium ammonium nitrate	1,23,837	1,67,939	2,36,348	1,80,022	1,28,268	1,07,327
Super-phosphate	15,066	21,282	56,394	23,913	6,121	19,863
Diammonium phosphate			42,662	24,470	47,014	54,862
Mixtures*	91	761	17,280	52,047	78,758	72,243

*Mixture means potash for 1962-68 onwards and NPK for 1972-73.

Source: Statistical abstract of Punjab (1973).

From the trends given above, it is evident that emphasis has already shifted from single nutrient use to more than one nutrient element carrier. The farming community here has already experienced the use of various high analysis and chemically pure fertilizers like triple superphosphate, ammonium phosphate, diammonium phosphate, urea ammonium phosphate, etc. A stage has been reached that the cultivators prefer to use compound and complete fertilizers over low analysis single-nutrient fertilizers

The exploitive agriculture as followed in the Punjab province has revealed a number of problems on nutrient use. These problems relate to the need of a particular nutrient element, its dose, the type of suitable carrier and the method and time of its application. The more significant problems are reviewed in the following paragraphs.

Sequential appearance of limiting nutrient elements

With the introduction of high yielding varieties of crops in 1965-66, the agriculture pattern in the province developed a new dimension. The high yielding varieties quickly replaced local tall and low yielding varieties (Table 6).

Table 6. Acreage under high yielding varieties in relation to total area under wheat in Punjab (x000 hectares).

	1970-71	1971-72	1972-73	1973-74
H.Y. Varieties	1589	1695	1890	1920
Total	2299	2336	2404	2387

The studies conducted in the Punjab, under irrigated conditions of wheat showed that the dwarf varieties remove differential quantities of nutrients from the soil as compared to indigenous varieties, thereby exert more stress on the soil for nutrient supply (Randhawa, et al., 1972)*. The varying response of these two kinds of wheats to added nutrients are shown in Table 7.

The dwarf varieties of wheat responded more to both N and P than the local varieties. It was quickly recognized that N was a significant limiting factor for wheat growth in Punjab soils, and the use of N-fertilizers became rather common; this continued and other nutrients were largely ignored. Field experiments conducted on nutrient responses during 1968-69 and subsequently (typical data in Table 8) showed that the response in wheat per unit of applied phosphate was of a higher magnitude than for nitrogen. The yields obtained from the application of N alone year after year had presumably resulted in the exhaustion of other soil nutrients, particularly phosphorus. The results of systematically planned experiments in the province have shown that in the cultivation of high yielding varieties, when manured with N only, it takes 1 to 2 crop seasons for a soil with normal supply of P to be depleted to a level at which crops cannot be produced satisfactorily, unless application of P to the soil is ensured. In other words, fields which are fertilized with N alone often tend to stabilize at a low level of yield production, unless the P needs are adequately met.

* Randhawa, M.S., Dev, G., and Randhawa, N.S. (1972). Paper presented at symposium on Soil Productivity, National Academy of Sciences, India, 358.

Table 7. Responses of representative local and high yielding wheat (q/ha) in Ludhiana district in Punjab.

Treatment	1966-67		1967-68		1969-70	1970-71
	C-306	High Yielding	C-306	High Yielding	High Yielding	High Yielding
N_1	6.06	6.25	2.91	4.33	6.8	7.76
N_2	7.19	13.37	5.00	7.01	10.1	11.15
P_1	2.53	2.36	3.41	5.53	3.4	4.89
N_1P_1	11.85	13.14	8.19	12.59	12.0	13.32
N_2P_1	14.67	21.13	11.45	17.85	16.8	18.62
N_2P_2	15.03	22.95	14.44	23.27	20.1	21.84
$N_2P_2K_1$ *	20.24	21.46	11.73	18.61	21.2	22.89
Control yield	26.51	25.21	19.40	26.27	22.0	22.01
L.S.D. (0.05)	5.82	6.17	1.17	1.82	1.6	1.69
Number of experiments	15	15	30	31	55	61

N_1N_2 represents 60 and 120 kg N/ha; P_1,P_2 represents 30 and 60 kg/P_2O_5 and K_1,K_2 30 and 60 kg K_2O/ha respectively.

During the year 1966-67, P_1, P_2 or K_1 and K_2 represent 60 and 128 kg P_2O_5 or K_2O/ha respectively.

*from year 1969-70 onwards K_2.

Source: Annual Report, All India Coordinated Agronomic Experiments Scheme. Punjab Agric. University, Ludhiana.

Table 8. Change in response of wheat in kg/kg of applied N or P_2O_5.

Year	Response in kg/kg of nutrient applied	
	N	P_2O_5
1966-67	11.0	12.4
1967-68	14.4	13.0
1968-69	6.0	27.0
1969-70	9.0	18.0
1970-71	9.2	18.6

The Punjab soils have high reserves of potash bearing primary and secondary minerals, and on weathering, they release enough K to meet the crop needs (Kanwar, 1959)*. Therefore, the responses to K application in Punjab soils are rather low (Table 9) and they are restricted to light textured soils only, especially where high levels of yields have been obtained by increased use of N and P.

Table 9. Effect of potash application on the yield of wheat in Ludhiana and Sangrur districts in Punjab.

Year	No. of trials	Yield of wheat grain (q/ha) with K_2O doses (kg/ha) of		
		0	30	60
		Ludhiana District		
1968-69*	31*	44.1	44.9	45.7
1969-70	55	44.0		45.2
1970-71	61	45.6		46.6
		Sangrur District		
1971-72	46	45.1	45.0	45.8
1972-73	47	41.4	41.0	42.3
1973-74	48	43.9	43.3	43.9

* Basal dressing of 120 kg N and 30 kg P_2O_5/ha; includes 22 experiments in Karnal (Haryana).

Source: Annual Reports, All India Coordinated Agronomic Experiments Scheme, Pb. Agri. Univ., Ludhiana.

The data in Table 10 provide experimental evidence to show that for exploiting the potential of high yielding wheat, major nutrient elements should be applied not only in adequate quantity but there has to be a proper balance in their application. The pattern of nutrient element used (N, P_2O_5, K_2O) in the Province is shown below

1962-63	1965-66	1968-69	1970-71	1971-72	1972-73
1:.08:.002	1:.07:.03	1:.14:.03	1:.18:.04	1:.23:.05	1:.29:.08

It is indeed satisfying to note that the trends in use of N : P : K ratio in the state has been improving steadily. However, efforts are required to ensure that this ratio attains the ideal value of 2:1:1 (the world target ratio is 1 : 1 : 1).

* Kanwar, J.S. (1959). J. Indian Soc. Soil Sci. 7:249.

Table 10. Performance of high yielding varieties of wheat in Ludhiana and Sangrur districts in Punjab to varying N and P combinations.

Year	No. of Experiments	Yield (q/ha)			
		Control	120-0-0	120-30-0	120-60-0
		Ludhiana District			
1968-69	31	26.27	33.28	44.12	49.54
1969-70	35	22.36	33.12	40.22	44.01
1970-71	61	23.09	34.39	41.83	44.55
		Sangrur District*			
1971-72	46	26.58	38.94	42.74	45.79
1972-73	47	26.19	35.32	38.03	42.23
1973-74	48	27.01	36.56	40.81	43.90

* In Sangrur district, a dose of 60 kg K_2O/ha is basal.

Source: Annual Reports, All India Coordinated Agronomic Experiments Scheme. Punjab Agricultural University, Ludhiana.

The exploitive nature of agriculture and more use of chemically pure high analysis fertilizers have increased the incidence of deficiency of zinc in Punjab soils. During the last 2-3 years, at a rather large number of sites, especially in light textured soils and under intensive cultivation practices, high yielding varieties failed to produce normal growth, in spite of fertilization with recommended doses of N, P, and K. In all such cases, nutrient element zinc has been demonstrated to be the limiting element. Application of 5 ppm Zn as $ZnSO_4$ in conjunction with NPK increased wheat yield by 25-43% at different locations (Takkar, et al., 1973).*

In the list of nutrient elements limiting crop yields in the Province, deficiency of S has also become of importance. The data in Table 11 indicate the magnitude of S responses in various wheat varieties. Deficiency of S has arisen essentially as a consequence of increased use of S-free fertilizers (Table 12).

Table 11. Effect of S application on yield of different wheat varieties at PAU farm, Ludhiana.

Treatment	Wheat Varieties			
S level (kg/ha)	K-227	S-308	PV-18	WG-357
0	24.6	23.4	26.3	28.1
25	29.4	33.9	32.8	31.0
50	32.1	31.4	34.4	32.0

* Takkar, P.N. et al. (1973). Indian Fmg. 23(8):5.

Table 12. Consumption of S-bearing and S-free fertilizers in India.

Fertilizer	Consumption* (thousand tonnes)			
	1965-66		1972-73	
	S-bearing	S-free	S-bearing	S-free
Nitrogenous	276.42	274.21	190.10	1550.30
Phosphatic	104.92	27.24	127.10	422.54
Potassic	3.25	74.52	1.87	360.53

* N, P_2O_5 and K_2O equivalent.

Realizing that the maintenance of high yield levels requires the detection of deficiencies of not only major nutrient elements, but of secondary and micronutrients as well, there is a growing appreciation for soil testing services. This has become of more importance, in view of the overall short supply of fertilizers. In the year 1957-58, there was only one Soil Testing Laboratory in the Province and at present, there is at least one Soil Testing Laboratory in each district (=municipality). The soil testing service is free in the Province and all the laboratories have the facilities to analyse about 150,000 soil samples annually. The fertilizer doses applied on the basis of soil test values have constantly given higher yields. There is an urgent need to develop soil test benchmarks, and recommendations suited for different crop rotations, rather than for individual crops, as at present. There is also a need to quantify fertilizer doses in accord with 'Target Yields' and tailored to defined soil groups of the Province.

Efficiency of different nutrient element carriers

The performance of different N carriers (ammonium nitrate, ammonium sulfate, urea) has been shown to be essentially similar for irrigated wheat in the Punjab soils; however the urea source has been found to give lower yields. For contrast, the effectiveness of phosphate carriers vary widely. The soils in Punjab are essentially alkaline in reaction and calcareous in nature and therefore water soluble P sources are the best suited. Due to the sulfur shortage in world markets, P-carriers which can be produced without sulfur are being encouraged for local production. In this group the efficiency of nitro-phosphate, with a variable water solubility, has become of importance. The data presented in Table 13 show that nitro-phosphate of 20 and 50 percent water solubility are 70 and 80 percent as efficient as a fully water soluble source of P for wheat However, for rice and corn, these nitro-phosphates compare rather favorably. In a wheat-rice rotation, where the nitric phosphate is added to paddy, the residual fertilizer phosphate insures good yields of wheat· it would appear that the nitric-phosphate used in a rice-wheat rotation is equivalent to superphosphate applied to wheat, in a wheat-rice sequence.

Table 13. Relative efficiency of different P-carriers in the Punjab.

Fertilizer	Yield (q/ha)		
	Wheat	Corn	Rice
Superphosphate	39.9	46.2	69.0
Diammonium phosphate	41.3	43.3	66.4
Ammonium nitro-phosphate			
30% W.S.	33.3	45.2	70.2
50% W.S.	32.7	44.2	

Source: Annual Report, All India Coordinated Agronomic Experiment Scheme, Pb. Agri. University.

The results of long-term field experiments (Table 14) show that wheat is more responsive to fertilizer P than a summer season cereal, i.e. corn. It has therefore been recommended that in wheat-corn rotation, if wheat has been receiving recommended P dose for continuously 3-4 years, P levels to be applied to corn can be safely lowered, without any detrimental effect on yield of corn.

Table 14. Average crop response to continuous P application in wheat-corn rotation (1968-69 to 1973-74).

P_2O_5 (kg/ha)	Average response (q/ha)	
	Wheat	Corn
30	12.0	4.8
60	15.5	2.8

Source: Salient Results of Field Experiments, Deptt of Soils, Pb. Agri. University.

Correct time and method of fertilizer application

The presence of a nutrient element in the soil during the growth period when rapid nutrient uptake occurs is essential for efficient use of fertilizer nutrient. It is therefore essential that fertilizers be applied at an optimum time, and insofar as practically possible, placed where the nutrient(s) is readily accessible to the plant roots. The Punjab soils are light in texture and contain low amounts of organic matter. Nitrate nitrogen is water soluble and therefore mobile in the soil. To save N from leaching losses, especially in light textured soils, its split application in wheat is usually recommended. The data given in Table 15 show that N applied in 3 equal splits and followed by light irrigation gave maximum fertilizer-use efficiency and produced the highest wheat yield. The results given in Table 16 show that for phosphate, its placement is far superior as compared to the broadcast method.

Table 15. Effect of split application of N on wheat yield.

Amount of each Irrigation (cm)	Yield (q/ha) with 150 kg N supplied in splits of			
	1	2	3	4
5.5	16.7	20.8	26.5	23.3
7.5	14.8	18.0	22.2	19.2
9.5	13.9	16.7	17.5	16.0

Source: Salient Results of field experiments, Deptt of Soils, Pb. Agri. University.

Table 16. Effect of method of phosphate placement on the yield of wheat.

Method of P Application	Dose (kg P_2O_5/ha)	Yield (q/ha)
Broadcast	30	39.5
	60	41.1
Drilled below seed	30	41.2
	60	44.1
Drilled below and on one side of the seed	30	40.3
	60	44.5
Control Yield		30.9

Source: Bajwa, M.S. and Dev, G. (1973) Indian Fmg. 23(9):13.

Efficiency of applied nitrogen under rain-fed conditions

In the Punjab, of the net area sown , about 72% is irrigated by various sources like canals, tube-wells, and storage tanks etc., and the rest is rain-fed. The results of field experiments given in Table 17 show that the efficiency of applied N depends to a great extent on the moisture stored in the soil profile. In the soil with more moisture stored in the profile, fertilizer N up to 80 kg N/ha or higher produced significantly more response of wheat grain, while in soil with low moisture storage, the dose giving economical response was of the order of 40 kg N/ha. It has therefore been considered desirable that under rain-fed wheat growing conditions, nutrient doses should be tailored to the soil moisture reserves.

Table 17. Efficiency of applied nitrogen in dry land wheat (yield in q/ha).

Treatment	Soil of high moisture storage		Soil of low moisture storage	
	1971-72	1972-73	1971-72	1972-73
0	15.8	22.5	19.0	23.2
40	29.8	37.0	32.9	27.9
80	38.5	41.6	35.5	33.4
120	46.0	39.1	34.5	34.9
L.S.D. (0.05)	1.9	0.9	2.5	2.1

Source: Singh, Y. (1973) M.Sc. Thesis, Pb. Agri. University, Ludhiana.

Efficiency of applied fertilizers on timely sown crops

In the type of agriculture, where sowing and harvesting involve little mechanization, agricultural operations are always slow and this results in staggering of the planting time of crops. With advances in agricultural technology, the use of machinery and time and labour saving implements have gained importance. However, in the Punjab, late sowing of wheat cannot always be avoided. The data given in Table 18 show that for late sown wheat, the efficiency of applied N is about 1/3 compared with timely sown wheat (Bains, 1974)*. With the late sown crop, due to low temperatures, probably the nutrient is not readily available and thus the crop is not able to utilize the nutrient fully.

Table 18. Comparative response of normal and late sown wheat to applied nitrogen (1972-73 to 1973-74).

N level kg/ha	Grain Yield (q/ha) with sowing dates of		
	Nov. 10 (Normal)	December 5	Dec. 30
0	11.1	9.4	7.0
60	37.4	30.1	13.9
90	41.2	33.6	17.6
120	47.9	34.1	18.1
150	45.5	33.8	18.0
180	42.9	33.7	18.0

* Bains, D.S. (1974) Paper presented at 13th All India Wheat Research Workers Workshop, Pb. Agric. University, Ludhiana.