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PERSPECTIVE OF INTEGRATING ORGANIC AND INORGANIC PLANT-NUTRIENT SOURCES FOR CROP-PRODUCTION IN PAKISTAN

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ABSTRACT

Pakistan is among those countries of the world which have high growth-rate of population, coupled with low crop-yield per unit area—much lower than several developed countries of the world. Therefore, we need to improve crop-yields through introducing high-yielding crop-varieties along with improved tillage-practices, fertilizers, water-irrigation, and pest-management. This paper addresses the problems of low use-efficiency of fertilizer and ways to improve it. The benefits and constraints to integrate the use of organic manures and inorganic fertilizers have also been discussed in some detail in the paper.

INTRODUCTION

For optimum crop-yields, adequate supply of nutrients is extremely important to growing-crops. Growing plants derive their nutrition principally from soil reserves, which are not inexhaustible, but need replenishment. Nutrients exist in different forms in natural ecosystem in dynamic equilibrium. Different pathways of nutrient-transformations in the natural ecosystem are shown in Figure-1. Supply of various nutrients to growing-crops in a particular system through all possible means, is the spirit of Integrated Plant-Nutrition System (INPS).

Four types of crops are principally grown in Pakistan: food-crops, cash-crops, food-legumes and edible oilseeds. Majority of the cultivated area is under food-crops (Table-1). During the 12-years period, the area under food-crops has expanded by about 10%, whereas production has increased by 26%. Similarly, the area under cash-crops registered a 26% expansion but the increase in production has been 61%. Interestingly, the areas under food-legumes and edible oilseeds remained static, but their production showed 44% and 106% increase, respectively. The overall index of agricultural production (Table-2) from the years 1980-81 to 1990-91 has shown an increase in area under all crops by about 12%, while their production increased by 42%(Ministry of Food & Agriculture, 1992). It is very encouraging to note that, although the area under fiber-crops increased by only 23%, but their production registered a record increase of 127% during the last decade. This breakthrough has been possible due to the evolution of better varities of cotton, coupled with effective measures of pest control and ridge-sowing.

Wheat is the principal staple food and its production is considered to be the most important constituent of the country's agriculture. Considerable attention is directed to elevate its production. The area under wheat cultivation, during the last decade, increased by 19% under irrigated conditions, whereas a slight decrease in area under rainfed agriculture has been reported (Table-3). In the recent past, total production of wheat has been around 19 million tonnes which is mainly produced on irrigated areas. Some increase in the yield of wheat under both irrigated and rainfed conditions has been registered during the last decade (Table-3). Higher yield of wheat obtained by progressive farmers with optimum management of technology, in various parts of the country, and remarkable wheat tonnage produced during the year 2000 in the country (above 21m tonnes) clearly indicates the existence of great potential for increase in yield of wheat, as well as in almost all other crops.

Since 1947, high population growth-rate has resulted in significant decreased in per capita area in Pakistan (Table-4). It has become a difficult task to feed the present population of over 130 million, with the present production of various agricultural commodities. A substantial quantity of wheat alone, worth several million US dollars, was being imported in addition to the import of edible oil and other agricultural commodities. Unfortunately the picture of present population growth-rate of 3%, the projected population and meeting their requirements for various agricultural commodities in the next few years is very discouraging (Table-5). Agriculture still contributes an important share to exportable commodities of the country (Table-6). It

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Table - 1: Area and Production of Different Categories of Crops in Pakistan (1979 to 1991)

Year	Food-Crops	Cash-Crops	Food-Legumes	Edible Oilseeds
(Area '000' ha)				
1979-80	10803	2865	1551	501
1984-85	11256	3200	1415	469
1989-90	11921	2505	1496	453
1990-91	11933	3601	1538	497
(Production '000' tones)				
1979-80	15592	28644	510	1775
1984-85	16692	33340	725	2355
1989-90	19313	37360	768	3267
1990-91	11933	46111	732	3664

Table - 2: Index of Agricultural Production (1980-81=100)

	Acreage Index				Quantum Index			
Year	All Crops	Food-Crops	Fiber-Crops	Other Crops	All Crops	Food-Crops	Fiber-Crops	Other Crops
1981-82	104	103	105	107	105	102	105	111
1985-86	105	106	112	91	120	114	170	89
1989-90	112	112	123	93	135	120	204	108
1990-91					142	122	227	113

Table - 3: Area, Production and Yield of Wheat Under-Irrigated and Non-irrigated Conditions in Pakistan

Year	Area ('000' ha)		Production ('000' tones)		Yield (kg ha^{-1})	
	Irrigated	Non Irrig.	Irrigated	Non Irrig.	Irrigated	Non Irrig.
1979-80	5454	1469	9567	1289	1754	877
1984-85	5764	1493	10533	1165	1828	780
1989-90	6458	1386	12883	1432	1995	1033
1990-91	6531	1398	1298	1581	1993	1131

Table - 4: Changes in per-capita area over the last four decades in Pakistan

Year	Per Capita Area (ha)	
	Total Area Basis	Cultivated Area Basis
1950-51	2.36	0.45
1960-61	1.86	0.42
1972-73	1.22	0.29
1980-81	0.94	0.24
1987-88	0.77	0.20

Table - 5: Projected Population and Requirements of Different Agricultural Commodities (in million tonnes) in Pakistan

Year	Population (million)	Wheat	Edible Oils	Sugar	Milk
1947	31	4.6	0.27	0.30	3.00
1960	42	6.2	0.36	0.40	4.00
1980	82	9.3	0.56	0.86	5.34
1990	110	13.5	1016	3.72	5.94
2000	148	22.2	1.97	6.25	9.50
2010	201	30.1	2.61	8.78	12.46
2025	317	47.5	4.12	12.57	19.65

appears to be an insurmountable task to feed the growing population in the coming decades, unless improved production programmes are implemented.

FACTORS AFFECTING NUTRIENT-USE EFFICIENCY

1. Agronomic Practices

Various agronomic practices, like crop-rotation, seed-bed preparation, sowing methods, cultural practices, crop variety, pest-control and irrigation, play a significant role in the efficient use of a particular plant-nutrient. With the optimum agronomic practices, more crop- yields can be harvested, using certain amounts of relevant nutrient.

2. Inherent Soil-Fertility

Due to the semi-arid to arid climate and peculiar soil conditions, rapid turnover of organic matter results in very low organic matter in soils. Consequently, soils have low N content, invariably requiring the addition of N for economic crop-yields. Unfortunately, the added nitrogenous fertilizers suffer tremendous losses of N by the processes of volatilization and denitrification, resulting in low N recoveries (of 35-60% of the added N) by crops. Additionally, more than 90% of the soils are deficient in P and a greater proportion of added P fertilizers is rendered unavailable to plants due to fixation (Muhammed and Salim 1989). The recovery of added P fertilizers by crops is about 20%. Mixing P fertilizers with organic manures and side–dressing of P fertilizer improve P use-efficiency under certain situations. At present, potassium fertilizers are only used for sugarcane, tobacco and potato production. However, mining our soils with continuous cropping, without adding K, may result in K depletion of the soils. Responses of added secondary nutrients and micro-nutrients have been noted in many crops, on different soils of the country. All these factors call for a balanced use of nutrients for optimum production of crop. However, due to soaring costs of mineral fertilizers, the majority of the resource-poor farmers (generally with small land-holdings) have been unable to use balanced fertilizers in optimum amounts, which has affected their crop-yields drastically.

3. Soil-Salinity and Waterlogging

Soil-salinity and waterlogging are the major problems impacting substantial agricultural production. More than 60% of saline-soils in Pakistan are sodic as well. The intensity of salinity and / or sodicity varies, and different categories of these soils occupy 12 million ha out of the surveyed area of 62 million ha. Each class of these soils has a varying degree of problem and requirements for their amelioration. Existence of saline/sodic patches in 4m ha are of particular concern, as these significantly reduce the crop-yields.

Various estimates of the area prone to waterlogging have been reported by different agencies. Approximately 8.0 million ha are reported to have the underground water-level within a depth of 150 cm. This produces root-anoxia of major agricultural crops, resulting in either total failure or their reduction in yield to various degrees. The problems of salinity /sodicity and waterlogging not only affect agricultural production, but are also associated with environmental and socio-economic development of the area (Sandhu, 1990).

Table - 6: Quantity (Thousand Tons) and value (Million US $) of Export of Major Agricultural Commodities

Item	1985-86		1990	
	Quantity	Value	Quantity	Value
Raw Cotton	638.5	331.6	282.6	382.4
Cotton Waste	9.6	3.5	67.7	44.3
Raw Wood	11.2	11.6	5.6	9.1
Fish	35.9	53.4	29.5	90.6
Rice	1316.0	221.1	1204.4	313.8
Fine Rice	260.50	112.1	466.4	98.2
Others	1055.5	42.27	38.0	115.7
Total	**3327.2**	**775.5**	**2794.2**	**1154.7**

Table - 7: Grain Yield (tonnes ha^{-1}) of Rice and Wheat as Affected by Partial Replacement of Mineral Fertilizer Prilled Urea (PU) with Various Green-Manure Crops and Farm-Yard Manure (FYM).

Treatments	Paddy, Yield	Wheat Yield
	tones ha-1	
Control	3.40 C	3.27 C
PU (100 kg N/ha)	4.50 B	3.96 B
S. aculeata+1/2PU	5.23 AB	4.56 A
S. rostrata + 1/2 PU	5.60 AB	4.40 A
FYM + 1/2P U	4.78 B	4.37 A
Sunhemp + 1/2 PU	5.88 A	4.20 AB
Guara + 1/2 PU	5.33 AB	5.50 A

Source: *Akhter, 1989*

Table - 8: Accumulation and Distribution of Biomass by Rice in Different Plant-Components, when N from Organic (*Sesbania aculeata*) and/or Inorganic (ammonium sulphate) Sources was Applied.

Biomass-yield (g/pot)				
Treatments	**Root**	**Straw**	**Root**	**Straw**
T1	13.5	21.6	16.8	51.9
T2	17.5	41.9	31.9	91.3
T3	14.2	12.9	24.7	71.9
T4	17.1	37.3	28.1	92.5
T5	17	42.2	29.5	75.8
LSD (P<0.05)	**1.9**	**2.5**	**2.2**	**3.1**

Source: *Azam, 1992*

Note: T1 (Control), T2 (100 kg – N/g Soil as 15 N-organic N), T3 (50 mg N/g, soil) As 15 N inorganic N), T4 (50mg N as 15 N-organic N + 25mg N as inorganic N), T5 (50mg N as organic N + 25mg N as 15 N inorganic N)

Table - 9: Nitrogen taken up (mg N/pot) by wheat plants from soil (FS), from organic source (FO) and from inorganic source (I.E). Details of treatments are the same as for Table 8. Figures in parentheses are percentage of total plant N derived from the respective source

Treatments	Total	FS	FO	IE
T1	256.7	256.7	--	--
		(100.0)	--	--
T2	487.7	410.55	77.15	--
		(84.2)	15.8	--
T3	366.8	341.84	--	24.96
		(93.2)	--	(6.8)
T4	420.7	356.85	38.14	16.66
		(87.0)	(9.0)	(4.0)
LSD ($p<0.05$)	2.9	27.8	2.7	2.3

4. Soil Erosion

About 11 million ha and 5 million ha are affected to varying degrees by water and wind erosion in Pakistan, respectively. These soils lose a substantial potential of crop-productivity. Fertile top-soil, removed, due to water-erosion from watersheds, is transported and silts up in dams, resulting in their low efficiency. Similarly, agricultural crops are damaged and environmental problems are created due to wind-erosion. Sub-mountainous and foot-hill regions in northern parts of the country are mostly affected by water-erosion, whereas wind-erosion is active in Thal, Thar and Cholistan areas.

5. Moisture Deficit

Semi-arid to arid climate results in severe shortage of moisture in many parts of the country for most of the year. Production of crops without supplemental irrigation is, therefore, a big risk. Although 40 MAF of water, flowing through rivers into the Arabian sea can be used for irrigation, but development of surface water-storage involves heavy expenditure. Presently, the farmers rely on some traditional soil-moisture conservation and rain-harvesting techniques, like contour-bunding, deep ploughing, terracing, and tree plantations on contours. All these measures are helpful in earning subsistence for the small farmers, but substantial increase in agricultural productivity from these lands under present management-practices is not possible. In many areas, where the ground-water recharge is satisfactory, water-pumping is economical, but the underground water contains appreciable amounts of soluble salts, resulting in their accumulation in soil- profiles; also the electricity tariff is very high.

Table - 10: Residual Effects of Urea, Compost or Compost + Urea applied at Various Rates to the Preceeding Rice-Crop on some Agronomic Parameters of Wheat.

g/pot

Treatments	Grain	Straw	Total	Grain/Straw
Control	3.27	2.57	5.78	1.27
Urea	4.99	2.69	7.68	1.95
Compost-1	5.29	2.11	7.4	2.5
Compost-2	4.79	2.41	7.2	1.98
Compost-3	4.82	2.06	6.88	2.33
Compost-1+Urea	4.85	2.49	7.34	1.95
Compost-2+Urea	5.16	2.66	7.82	1.94
Compost-3+Urea	4.66	2.39	7.05	1.95
LSD($p<0.05$)	0.34	0.18	0.42	0.82

Source: *Azam, 1990*

Note: Comp-1,2 & 3) refer to Kallar grass compost applied @ 2.5,5.0 and 10.0 tones/ ha and urea applied @ 10 N/ha

Table - 11: Effect of Rhizobium Strains (NC 92 and Rudi Patrik) and Nitrogen Fertilizer (@ 100 kg N/ha) Application on Dry Matter at Maturity and Dry Pod Yield of Groundnut

Treatments	Dry matter kg/ha			Dry pod yield kg/ha		
	ICGS-4	ICGS-44	BANKI	ICGS-4	ISCS-44	BANKI
Control	2769DE	2138 E	4415 A	21158 C	2040 C	3033 A
Nitrogen	2291 E	2305 E	3199 CD	2019 C	2124 BC	2332ABC
NC 92	161 CD	2772 DE	363 IBC	2880 A	2018 C	2824 A
Rudi Patrik	3361 CD	3255 CD	4153 AB	2469 ABC	644 AB	2679 ABC

Source: *Shaheen, 1990*

6. Physical Conditions of Soil

Due to low organic-matter and weak soil-structure, soils have a tendency to develop crust on their surface in an area of about 12 million ha. Similarly in more than 2 million ha, where wheat or other crops follow rice cultivation, serious problems in seed-bed preparation and other cultural practices are encountered as physical conditions of soil are strongly modified, during puddling for rice cultivation. In dense sodic soils, the hydraulic conductivity is very low, which makes their amelioration difficult if not impossible. Poor physical conditions of soil retard the seedling emergence; restrict root-development and hamper oxygen, water and nutrient availability to roots of plant, ultimately badly affecting the crop-yields.

ROLE OF INTEGRATED PLANT-NUTRITION SYSTEMS (IPNS)

The increasing cost of mineral fertilizers and growing environmental problems lead to the adoption of IPNS (Hussain and Jilani, 1992). Unfortunately, no extensive implementation of the IPNS concepts has been seen physically in the country, though its importance is realized. The following are representative examples in action, which address various aspects of IPNS.

1. Green Manuring: Several plants like *Sesbania-aculeate, Sesbania-rostrata, Crostalari-ajuncea* and *Cyamiopsis- tetragotioloba* are used for green manuring. However, S. aculeata has gained more popularity in recent years, due to its fast growth, extensive foliage, higher N-fixing capacity, easy decomposition of the material in soil and salt-tolerance capacity. Significant increase of yield in rice and wheat have been recorded when various green-manure crops and farmyard manure have been applied, in combination with prilled urea (Table-7). Data indicate a more or less similar effect of various green- manure crops on improvement of yield of the two crops (Azam, 1992).

Table - 12: Rhizobium Isolates Maintained for Various Crops at National Agricultural Research Center, Islamabad, Pakistan

Crops	Strains
Arachis hypogea (Groundnut)	TAL 205, TAL 1000, IC 700, IC 7029, IC 7114, TAL 1371, NAA 7, IC 7017 IC 7113
Cicer arientinum (Chickpea)	TAL 620, TAL 480, NAA 3, NAC 6, NAC 8, NAC 11, NAC 14, NAC 20, IC 59, IC 76, IC 14920, IC 2002, IC 2092
Glycine max(Soybean)	TAL 102, TAL 378, TAL 379, NAG 12, NAG 13
Lathyrus spp (Peas)	TAL 634, NAL 1, NAL 16
Lens culinaris (Lentil)	TAL 638, TAL 640
Medicago spp (Medics)	NAM 2, NAM 14, F1, F100
Cajanus cajan	IC 3069, IC 3100, IC 3195, IC 4059, IC 4060
Phaseolus vulgaris	TAL 182, TAL 1383, TAL 1797
Sesbania spp	NAS2, NAS 4, NARI
Trifolium spp	PSHI/FAO, PSH2/FAO, PSH3/FAO, QU 12, NAT 6,
Stylosanthess spp	TAL 658
Vicia spp	NAV 3
Vigna spp	NAV 5, TAL 169, TAL 173, TAL 420, TAL 20

Table - 13: Biomass-Production of Rice (KS-282), Grown under Saline-Sodic Soil, Amended with Gypsum and Farmyard Manure at Satiana, Faisalabad.

	Control	Gypsum @ 50% GR	Gypsum @ 100% G	Gypsum @50+50%	Farm Yard Manure	Farm Yard Manure Gyps @50+50 %GR
Tiller	16.00c	16.92 bc	16.92 be	17.42 bc	25.33 a	24.42 ab
Grain Yield	0.693b	1.059 ab	1.338 ab	1.354 ab	1.130 ab	1.690 a
Straw Yield	2.438b	2.571 b	3.078 ab	3.229 ab	3.719 ab	4.379 a

Source; NARC, 1991

In a pot study, the effects of ammonium-sulphate (AS) and S. aculeata (SAC), labelled with 15N were studied, alone and in combination. Plant-height, number of tillers, spike-weight and number of rice gains were significantly affected by various treatments, as compared to control. Application of organic N alone, or with inorganic N, resulted in significantly more positive effects on various parameters, as compared to inorganic N alone (Table-8). Similarly, more N was taken up by rice plants when organic N and inorganic N were applied together, as compared to organic N alone (Table-9). A higher proportion of N from the organic source was used by rice plants, as compared to that from the inorganic N source (where maximum contribution to plant-N was from the soil). Comparatively more N for plant-use was released from the organic source, as compared to the inorganic source where N was applied from both the organic and inorganic sources.

2. Organic Composts: Kallar grass (Leptochloa fusca L. Kunth) is recognized as a salt-tolerant grass. It produces a good amount of biomass on degraded soils in summer. It has a marginal to acceptable value as a fodder for livestock. In a study, on mass-scale composting of Kallar grass, the compost was ready in approximately three months. This compost was compared in the field with urea at three rates alone, and in combination with 100 kg urea N ha^{-1}. Rice and wheat crops were grown. In the first crop of rice, urea alone produced more grain and straw yield than all the other treatments. Beneficial effects of application of compost at 2.5, 5.0 and 10 tonnes ha^{-1} were not observed on crop-yield, whereas its combination with urea-N showed improved yield of rice as compared to control. However, when a wheat-crop was grown after rice, the residual effects of various compost treatments were noticed (Table-10). Wheat grain and straw yields with compost treatments were comparable with those obtained by combined application of compost and urea. This clearly shows the beneficial residual effect of organic compost use for the succeeding crop (Azam, 1990).

3. Exploitation of Soil Microflora: Various soil micro-organisms fix atmospheric N and enhance the availability of indigenous soil-nutrients. In a field experiment, the performance of three strains of rhizobium was studied on three cultivars of groundnut. Significant specificity of groundnut cultivar ICGS-4 with rhizobium NC 92 was found, and relative increase in pod-yield and dry-matter was 36% and 14%, respectively, over the control (Table-11). Similarly groundnut cultivar ICGS-44 showed a significant specificity with the rhizobium strain Rudy Patrik and the increase in pod-yield and dry-matter yield over the control was 30% and 52%, respectively. It is interesting to learn that, in the same experiment, application of 100 kg N /ha did not increase pod-yield of any of the three groundnut cultivars. Realizing the important role of rhizobium inoculation in commercial crops, several microbial inoculants are now available from different research institutes in the country. A list of rhizobium isolated from 13 leguminous crops has been maintained at the National Agricultural Research Centre, Islamabad, which are listed in Table-12.

4. Use of Organic Amendments on Salt-affected Soils

Organic manure was used alone, and in combination with gypsum, for producing KS-282 variety of rice on a saline-sodic soil in a farmer's field in Satiana, District Faisalabad. Gypsum was applied according to gypsum requirement (GR). Use of gypsum @ 50% GR with organic manure significantly produced better paddy-yield of rice, as compared to single application of either gypsum or organic manure (Table-13).

CONSTRAINTS TO THE ADOPTION OF IPNS

In spite of the demonstration of successful role of IPNS in several places, the adoption on a mass scale is still far off. Some of the possible reasons are as follows:

i) Due to rapid growth of population, the requirements for fuel have been increasing tremendously. Such increase in fuel-requirements has not been matched by the development of energy-resources like electricity, fossil fuel, solar energy, etc. This results in the use of livestock-dropping, crop-residues, shrubs, tree foliage, grasses, parts of crop-plants, etc., as fuel, especially in the rural areas. Provision of alternate energy-sources in rural areas is essential to off- set this constraint.

ii) Shortage of fodder for livestock is a serious problem in many parts of the country. Farmers prefer to grow fodder-crops instead of green-manure crops and use wheat and rice straw as fodder. Development of the livestock-feed industry, production of fodder on barren marginal soils and management of rangelands of the country will improve the situation.

iii) Water and fertilizers are two major inputs, which are limited and expensive. Farmers prefer to utilize these two inputs for the production of cash and food-crops, instead of cultivating green-manure crops. Better management of available water and fertilizer, coupled with development of water resources of the country may provide relief from this constraint; whereas these could be substituted by forest by-products, if properly developed.

iv) Although the use of microflora has tremendous potential in IPNS, this technology is not well known or accessible to the common farmer. Commercialization of this useful technology is now essential to boost the role of IPNS in the agricultural development of the country.

v) The country has recently launched a National Conservation Strategy to off-set environmental hazards and ensure the sustainability of the resources. To achieve the objective of this strategy, it is essential to implement this in full spirit and in totality.

CONCLUSIONS

Unless improved production-technologies are followed, difficulty of feeding the growing population will be deserved in the decades ahead. Application of chemical fertilizers occupy a pivotal place in improving crop-yields, along with better pest-management and sowing of high-yielding crop-variety seeds. However efficiency of chemical fertilizers, added to various crop, is notoriously low due to specific soil and climatic conditions.

Different measures to improve use-efficiency of fertilizer for realising economic crop-yields have been discussed. Constraints and the role of using organic manures and biofertilizers/microbial inoculum for balanced nutrition of plants for higher crop-yields have been highlighted.

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