Prospects of Using Biofertilizers for Crop Production in Pakistan

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Introduction

Pakistan, like other underdeveloped countries, has a food shortage problem. The current population of 115 million is predicted to increase to 154 million by the year 2001 (NIPS, 1989). Further, additional land is being removed from cultivation each year because of such degradative processes as salinization, waterlogging, and erosion. This situation makes the problem of food production and human nutrition more acute. In view of this, there is an urgent need to increase the rate of food production on existing cropland to keep pace with our current rate of population increase which is approximately 3 percent per year. Consequently, our food grain production must also increase at the same rate to maintain an acceptable level of self-sufficiency. This will require an increase in agricultural production per hectare of land. Although there has been an appreciable increase in total agricultural production in recent years, Pakistan's average crop yields are among the lowest in the world.

To meet our present and future food production goals, we have adopted high yielding and disease resistant varieties, application of balanced fertilizers, improved agricultural practices, and application of suitable plant protection measures. However, maintenance of soil fertility/produc-tivity is becoming more difficult because of intensive production of food crops, excessive tillage, depletion of soil organic matter, increased soil salinity, poor drainage, and deterioration of water quality, especially for irrigation. Applied nutrients are lost through volatilization, denitrification, runoff, and leaching.

Soil microorganisms and their metabolic products can contribute substantially to restoring the tilth, fertility and productivity of agricultural soils. Use efficiency and crop yields can be markedly enhanced through the use of bacterial cultures (Hussain, 1979; Akhtar, 1990). Many workers (Hussain, 1979, 1983; Akhtar, 1982, 1986) experimented with microbes and their products on fertilized, unfertilized, sterilized and unsterilized soils. Hussain (1979) reported a 9.5 and 7.8 percent increase in grain and straw yields of Maxi-Pak variety of wheat, respectively, in response to inoculation with *Azotobacter chroococcum*. In another experiment, Akhtar (1990) obtained an 11.4 to 42.7 percent increase in the yield of various field crops through the use of a saprophytic soil fungus identified as *Arachniotus* sp. (Akhtar, 1982). This paper presents a summary of the research conducted in Pakistan on improving crop yields through the use of beneficial soil microorganisms.

Experimental Results

Improvement in Soil Fertility/Produetivity with Microorganisms

Azotobacter. *Azotobacter*, a symbiotic nitrogen fixing bacterium, was isolated from different locations in the Punjab Province of Pakistan. Maize seed, inoculated with *Azotobacter*, was grown with and without the addition of N and P at rates of 125 and 40 kg ha^{-1}, respectively, and resulted in increased grain yields of 19.8 and 15.9 percent, respectively, when compared with corresponding controls (Table l). Inoculation with *Azotobacter* strains was more effective in unfertilized than in fertilized soil. Fertilizer increased the yield by 21.2 percent; inoculation with *Azotobacter* increased it by 15.9 percent.

Rhizobium. Inoculation of soybean with various strains of *Rhizobium japonicum* significantly enhanced nodulation and nitrogen fixation, which resulted in a substantial increase in the harvestable grain (Table 2). Maximum increases in grain yield over the controls were 73.8 and 64.3 percent for Bragg and Lee cultivars, when inoculated with strains imported from Czechoslovakia (D- 178/CRIPP) and isolated from Rawalpindi (Punjab), respectively. Fertilizer had been applied at rates of 25 and 40 kg ha^{-1} of N and P, respectively.

Table 1. Effect of Seed Inoculation with Different *Azotobacter* Strains on Maize Grain Yield When Sown in Fertilized and Unfertilized Soils.

Strain No.	Unfertilized Yield ($t\ ha^{-1}$)	Yield Increase (%)	Fertilized Yield ($t\ ha^{-1}$)	Yield Increase (%)
A0	5.87bc	-	7.11cde	-
A1	5.72bc	-1.5	6.63c	-6.7
A2	5.97bc	1.7	7.33bcde	3.1
A3	6.86ab	16.9	8.24a	15.9
A4	5.72c	-1.5	6.83de	3.9
A5	6.72abc	14.5	8.14abc	14.5
A6	6.32abc	4.5	7.63abcd	7.3
A7	6.67abc	13.6	8.14abc	14.5
A8	6.57abc	11.9	7.85abc	10.4
A9	7.03a	19.8	8.24a	15.9
A10	6.60abc	12.4	6.89abc	3.1
A11	6.42abc	5.6	7.84abc	10.3

Treatment means in a column sharing the same letter are not significantly different at the 5% probability level.
Source: Hussain *et al*. (1987)

Table 2. Effect of Seed Inoculation with Different Strains of *Rhizobium japonicum* on the Yield of Soybean Cultivars Bragg and Lee.

Strains	Bragg		Lee	
	Grain Yield ($kg\ ha^{-1}$)	Yield Increase (%)	Grain Yield ($kg\ ha^{-1}$)	Yield Increase (%)
Control	296.6	-	174.9	0
Rawalpindi 1	402.5	35.6	287.5	64.3
Rawalpindi 2	301.4	1.6	237.1	35.5
Rawalpindi 3	311.3	4.9	237.4	35.6
Mansehra 1	384.0	29.4	237.1	35.5
Mansehra 2	367.7	23.7	229.4	31.1
Abbottabad	437.7	48.3	196.8	13.0
Peshawar	350.2	18.0	244.8	40.8
311b-110	317.7	5.2	215.0	22.7
311b-122	323.8	9.1	276.7	58.1
311b-142	379.2	27.8	242.4	38.5
311b-143	339.4	16.7	214.3	22.6
D-211/CRIPP	413.5	39.4	216.5	23.7
D-156/CRIPP	369.8	24.7	201.1	14.9
D-177/CRIPP	386.6	30.3	228.0	30.3
D-178/CRIPP	515.5	73.8	215.8	23.3
D-212/CRIPP	279.6	0.8	191.0	9.1

Source: Hussain and Arshad (1984)

Blue Green Algae. Blue green algae isolated from soils of Gujrat, Sheikhupura and Faisalabad were added to pots along with P and K at 24 and 45 kg ha^{-1}, respectively, before rice (variety IR-6) was grown. The results (Table 3) showed that, in most cases, the application of algae increased grain yield significantly. Grain yield with Sheikhupura No. 2 and PK was 36.8 percent higher than with PK alone, and 40.3 percent higher than the control.

Table 3. Effect of Blue Green Algae (BGA) on Yield of Paddy Rice.

Treatment	Rice Yield (g pot^{-1})	Yield Increase (%)
Control	28.5e	-
NPK	29.5de	3.5
PK	29.5de	3.5
PK + BGA (Gujrat No. l)	34.5bc	21.0
PK + BGA (Gujrat No. 2)	36.7ab	28.9
PK + BGA (Faisalabad No. 1)	34.5bc	21.0
PK + BGA (Faisalabad No. 2)	31.0cde	8.8
PK + BGA (Faisalabad No. 3)	33.7bcd	18.4
PK + BGA (Sheikhupura No. 2)	40.0a	40.3

Rate of fertilizer applied: N at 55 kg ha^{-1}; P at 24 kg ha^{-1}; K at 45 kg ha^{-1}.
Treatment means sharing the same letters are not significantly different at the 5% probability level. Source: Hussain (1983)

Fungi. Studies to determine the effect of inoculating soil with the fungus *Arachniotus* sp. on the yield of wheat and rice were recently initiated in Pakistan. Experimental data support the hypothesis that this fungus increased the yield of wheat grain and its content of N, P and K. The best results were achieved when it was applied at a rate of 10 kg ha^{-1} along with chaffed wheat straw amended with urea (12.5 kg ha^{-1}) in fields where large applications of fertilizers (120-90-60 kg ha^{-1} of N-P-K) had failed to give any significant response (Table 4). The increase in grain yield in nutrient depleted soil was equivalent to the yield obtained through the application of fertilizer valued at about three times its estimated cost.

Table 4. Effect of *Arachnlotus* sp. on Grain Yield and Uptake of Nitrogen, Phosphorus and Potassium by Wheat.

Treatment	Grain Yield (kg ha^{-1})	Yield Increase (%)	N-uptake in Grain (kg ha^{-1})	P-uptake in Grain (kg ha^{-1})	K-uptake in Grain (kg ha^{-1})
Control	3736e	-	39.8f	10.0d	16.6d
Wheat straw (198 kg ha^{-1}) + urea (12.5 kg ha^{-1})	4296bc	15.0	57.2bc	12.9cd	20.2bc
Fungus inoculum (5 kg ha^{-1}) + T2	4393ab	17.6	59.6ab	13.7bc	21.3ab
Fungus inoculum (10 kg ha^{-1}) + T2	4595a	23.0	64.8a	17.0a	23.4a
Fungus inoculum (5 kg ha^{-1}) + T2 + NPK (120-90-60 kg ha^{-1})	4046cd	8.1	50.8cde	16.1ab	21.1ab
Fungus inoculum (5 kg^{-} ha^{-1}) + T2 + NPK (60-45-30 kg ha^{-1})	4065cd	8.9	51.9cd	13.7bc	20.3bc
NPK (120-90-60 kg ha^{-1}) + T2	3945cde	5.6	46.0cef	13.8bc	18.5cd
NPK (120-90-60 kg ha^{-1})	3926cde	5.1	44.3ef	12.8d	18.1cd

Treatment means in a column sharing the same letters are not significantly different at the 5% Probability level.
Source: Akhtar (1990)

In the case of rice, addition of the fungal biofertilizer increased the yield by 20 percent over the control (Table 5). The fungal biofertilizer also solubilized the relatively insoluble forms of phosphorus particularly under the complex calcareous soil environments. It is obvious from the data (Table 6) that P uptake by wheat was significantly increased in the presence of the fungus *Arachniotus* sp. Under sterile conditions maximum increase in P uptake (30.6 percent) was observed with the fungal treatment along with 24 mg P per pot; however, under non-sterile conditions, P uptake was 12.1 percent when the fungus was applied with no addition of P. Furthermore. P up-take was decreased with increasing P application. In this case, the addition of P may have stimulated the activity of indigenous soil microorganisms that were antagonistic toward *Arachniotus* sp.

Table 5. Effect of the Addition of *Arachniotus* sp. on the Yield of Paddy Rice.

Treatment	Average Yield (kg ha^{-1})	Yield Increase (%)
Control	3483	-
Chaffed wheat straw alone + 1% N	3982	14.3
Chaffed wheat straw + 1% N + *Arachniotus* sp.	4179	20.0

Source: Akhtar (1982)

Table 6. Phosphorus Uptake by Wheat Grain as Influenced by the Application of Phosphorus and a Fungus Inoculant (*Arachniotus* sp.) in Sterilized and Unsterilized Soils.

Treatment (mg P kg^{-1} soil)	Sterilized Soil			Unsterilized Soil		
	With Fungus (mg Pot^{-1})	Without Fungus (mg Pot^{-1})	Increased Uptake (%)	With Fungus (mg Pot^{-1})	Without Fungus (mg Pot^{-1})	Increased Uptake (%)
0	120	106	13.2	102	91	12.1
2	143	122	17.2	130	114	14.0
24	163	125	30.6	148	131	13.0
48	159	131	21.4	136	147	-7.5

Source: Rashid *et al*. (1985).

Azospirillum. An isolate of *Azospirillum* was used in the inoculation of wheat seed (Table 7) and showed that *Azospirillum* alone increased wheat grain yield by 47.9 percent over the control. However, when *Azospirillum* was applied in combination with P and NP, grain yields increased by 28.4 and 14.2 percent, respectively, compared with the application of P and NP alone.

Table 7. Effect of Fertilizer Treatment with and without *Azospirillum* on Yield of Wheat.

Treatment	Grain Yield (g pot^{-1})	Yield Increase (%)
Control	27.1	-
Azospirillum	40.1	47.9
P	35.2	-
P + *Azospirillum*	45.2	28.4
NP	43.4	-
NP + *Azospirillum*	49.6	14.2

Source: Azad (1990)

Green Manure. A three-year study was conducted to evaluate green manures as a substitute for synthetic N fertilizer in a rice-wheat rotation. Green manure crops grown for 35 days (Table 8) were incorporated into the soil before transplanting rice. N was applied at 87 kg ha^{-1} (50 percent from green manure and 50 percent from urea) along with a basal application of P and K fertilizers. Following rice, a wheat crop was sown to determine the residual effect of the organic amendments compared with the recommended application of fertilizer on wheat. All green manures improved rice yields considerably; however, the average maximum paddy yield was achieved with sunnhemp. The lowest yield, except for the control, was recorded with urea alone. This result clearly demonstrates the benefit of green manure plus urea over chemical fertilizer alone. Similar results were obtained after planting a second crop of wheat,

Table 8. Effect of Green Manure on Rice Yield and Residual Effect on Wheat Grain Yield.

Treatment	Total N Applied (kg ha^{-1})	Rice Yield (t ha^{-1})	Wheat Yield (t ha^{-1})
Control (no nitrogen)	-	3.01	2.32
Urea only (no GM)	87	4.68	2.93
GM (*S. aculeata*) + urea	87	5.01	4.31
GM (*S. rostrata*) + urea	87	5.25	3.64
GM (Sunnhemp) + urea	87	5.29	4.40
GM (*Guara*) + urea	87	5.19	4.65

Source: Hussain and Jilani (1991)

Sugar Industry Waste Compost. The application of composted sugar industry wastes increased the grain yield of wheat (Table 9). The average maximum grain yield was obtained with NP + compost at 10 t ha^{-1}. In general, all the treatments significantly increased the organic matter content of the soil. The results indicated that composted sugar industry waste can be used successfully to improve crop yields as well as soil fertility and productivity.

Table 9. Effect of Composted Sugar Industry Waste on Wheat Grain Yield and Soil Organic Matter Content.

Treatment	Grain Yield (q ha^{-1})	Soil O.M. (%)
Control	28.1d	0.53d
NP	49.1b	0.54d
Compost at 5 t ha^{-1}	37.4c	0.76c
Compost at 10 t ha^{-1}	44.3b	0.88b
NP + compost at 5 t ha^{-1}	63.5a	0.78c
NP + Compost at 10 t ha^{-1}	66.3a	0.94a

Treatment means in a column sharing the same letters are not significantly different at the 5% probability level.
Source: Azad (1989)

Farmyard Manure. Regular additions of organic materials such as animal manures and crop residues are very important in maintaining the tilth, fertility and productivity of the soil. The data (Table 10) show that the application of farmyard manure (FYM) increased the yield of fresh biomass of maize both in "normal" and saline-sodic soils. The addition of green manure produced higher yields than FYM, especially at low rates of fertilizer N.

Table 10. Effect of Farmyard Manure on Yield of Fresh Biomass of Maize under Normal and Saline-Sodic Conditions.

FYM (t ha^{-1})	Normal Soil (g pot^{-1})	Saline-Sodic (g pot^{-1})
0	350	223
6	410	240
12	462	275
18	504	311

Source: Ali (1990)

Poultry Manure. Poultry manure (PM) increased rice yields over the control (no fertilizer) and N alone. Similarly there was much improvement in paddy yield with the application of PM plus NP over NP alone, although total N applied in both the cases was same (Table 12). The average maximum yield was obtained from PM application (1/4 N as prilled urea. and 3/4 N as PM) coupled with NPK, followed by a second PM application (l/2 N as prilled urea and l/2 N as PM) coupled with NPK.

Table 11. Effect of Green Manure and Farmyard Manure on Fertilizer Use Efficiency of Rice Yield.

Treatment Matter	**Fertilizer Level (kg ha^{-1})**				
	Control	**75-60-0**	**75-90-0**	**150-60-0**	**150-90-0**
GM	2200	3173	3297	3648	3774
FYM	1976	2873	3046	3624	3718
Fallow	1637	2525	2812	3562	3627

Source: Mian *et al*. (1988)

Table 12. Effect of Various Combinations of Chemical Fertilizers and Organic Amendments on Rice Yield.

Treatment*	**Rice Yield (t ha^{-1})**
Control	0.76
N	1.63
PM (Full dose on N basis)	1.89
NP	1.82
NP + PM (1/2 N as PU; l/2 as PM)	2.27
NPK	2.02
NPK + PM (1/2 N as PU; 1/2 as PM)	2.32
NPK + PM (1/4 N as PU; 3/4 as PM)	2.75

*PM - Poultry Manure; PU - Prilled Urea
Source: Shahid (1990)

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