Vol. XIX (1-2) 1982

A NEW BIOLOGICAL APPROACH TO BOOST CROP PRODUCTION

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Preliminary investigations to enhance the crop yield through the use stimulatory microbes have been made. Addition of *Arachniotus* sp. alongwith chaffed wheat straw (80 to 320 kg/acre) unamended or amended with 1-4 percent N or NK to the field during seed bed preparations was found to enhance the yield of wheat grain by 24.4 to 42.7 percent, rice paddy by 20 percent, maize cobs by 11.4 percent, sugarcane by 26.9 to 38.8 percent and Berseem fodder by 32.7 percent. Similarly the addition of *Streptomyces ulra* alongwith chaffed wheat straw (80 kg/acre) amended with 2-4 percent NK enhanced the yield of wheat grain by 6.3 to 29.0 percent and Berseem fodder by 15.2 percent. Investigations on the residual effect of *Arachniotus* sp. application on the yield of wheat grain yielded an average increase of 73.8 percent.

INTRODUCTION

The rapid increase in population has spurred the agricultural scientists to strive hard to increase the food production per unit area. All the possible means to increase food production like the use of high yielding and disease resistant varieties, application of balanced fertilizers, adoption of improved agricultural practices and suitable plant protection measures are being advocated. The role of soil microbes in contributing towards raising of soil fertility and crop yields is gaining importance day by day. The Russian scientists have reported that the yields obtained by the use of artificial fertilizer and improved agricultural practices etc. can be increased further through the use of bacterial cultures. Increased crop yield of, 10-20 percent by seed inoculations with Azotogen (a commercial prepatation of *Azotobacter chroococcum*) has been claimed (Balis, 1946). Crops viz. corn, oats, wheat, barley, sugarbeet, potatoes, cabbage, tomatoes and carrots were stated to response to Azotobacter inoculations and give an increase of 10 percent in yield (Alexender, 1961). Increased yield of 25.3 percent in potatoes, 19.0 percent in cabbage and 28 percent in tomatoes by seed inoculations with *A. chroococcum* in heavily manured soils was reported

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(Mishustin *et al.*, 1963). Hussain (1979) obtained 9.5 and 7.8 percent increase in gram and straw yields of Maxi-Pak variety respectively. The author during his recent studies on the biological control of soil borne plant pathogens noticed that with the application of certain specific microbes, the yield of some crops was greatly enhanced. This fact led to the initiation of regular studies on the stimulatory effects of the antagonistic microbes on the growth and yield of crops. The results achieved so far are presented in this paper.

MATERIALS AND METHODS

Antagonistic microorganisms

Antagonistic soil sepraphytes namely *Arachniotus* sp. and *Streptomyces atra* were used in the present studies. *Arachniotus* sp. was isolated from local soils using the needle method (Akhtar, 1966) while *S. atra* was obtained from Dr. Abdul Ghaffar, Professor of Plant Pathology, Karachi University, Karachi.

Dose of inoculum and substrate

Finely chaffed (machine threshed) wheat straw with or without amendments was used at the rate of 90 to 320 kg/acre. The inoculum of the antagonistic organisms obtained from two 9 cm petri plate cultures was used for contaminating 1 kg of the substrate.

Experimental technique

The chaffed wheat straw (machine threshed) as such or amended with 1-4 percent of its weight of N or NK was moisened and mixed throughly with the suspensions of the antagonistic organisms and scattered uniformly in the fields during the seed-bed preparations. It was mixed in the soil by ploughing the fields twice after broadcasting.

EXPERIMENTS AND RESULTS

1. WHEAT

To study the effect of stimulatory microbes on the yield of wheat crop three experiments were conducted. Two stimulatory organisms namely *Arachniotus* sp. and *S. atra* were used. In the first two experiments the effect of fresh application of these microbes applied separately and in combination to the soil during seed bed preparation alongwith chaffed wheat straw (used @ 80

kg/acre) amended with 2.4 percent of its weight of NK on the yield of wheat was investigated. In the third experiment the residual effect of the *Arachniotus* sp., previously applied to the maize crop in May, 1981 alongwith chaffed wheat straw amended with 2 percent N (used at the rate of 80 kg/acre), on the yield of wheat was studied. All the three experiments were laid out in random blocks with four replications. In the first experiment the chaffed wheat straw used was amended with 2 percent NK, and the experiment was sown on 11.11.81 with variety LU 26, in plots measuring 30' × 18'. The second experiment which was sown on 26.11.81, with variety LU 26, in plots measuring 40' × 18' was split into two sets of two repeats each. In one set the chaffed wheat straw was amended with 2 percent NK and in the second set it was amended with 4 percent N.K. The third experiment was sown on 18.12.81 with variety Maxi-Pak, in plots measuring 12' × 40'. All the three experiments were harvested in the first fortnight of May. The results obtained are presented in Tables 1, 2, and 3.

TABLE 1. *Effect of addition of stimulatory microbes to the soil, alongwith chaffed wheat straw (80 kg/acre) amended with 2 percent NK, on the yield of wheat, in the normal sown crop.*

S. No.	Treatment	yield in kg /acre					% increase over control
		R I	R II	R III	R IV	Average	
1.	Control	1740.8	1694.0	1887.6	1573.0	1736.3	—
2.	Chaffed wheat straw amended with 2% NK	2081.2	1597.2	2057.0	1742.4	1869.4	7.6
3.	T. 2 + *Arachniotus* sp.	2662.0	2323.2	2613.6	2081.2	2420.2	39.3
4.	T. 2 + *S. atra*	2274.8	1984.4	2371.2	2081.2	2178.0	25.4
5.	T. 2 + *Arachniotus* sp. + *S. atra*	1984.0	1936.0	2323.2	2178.0	2105.4	21.2

TABLE 2. *Effect of addition of stimulatory microbes to the soil, alongwith chaffed wheat straw amended with 2 percent and 4 percent doses of NK in the crop sown in the end of November*

S. No.	Treatment	yield in kgs/acre							
		Chaffed wheat straw amended with 2 per cent NK				Chaffed wheat straw amended with 4% NK			
		RI	RII	Average	%Increase over control	RI	RII	Average	%Increase over control
1.	Control	1548.8	1524.6	1536 2	–	1597.2	1403.6	1500.4	–
2.	Chaffed wheat straw +NK	1694.0	1452.0	1573.0	2.3	1742.4	1548.8	1695.6	9.6
3.	T. 2+*Arachniotus* sp.	2018.2	1742.4	1911.8	24.4	2444.2	1839.2	2141.7	42.7
4.	T. 2+*S. atra*	1766.6	1500.4	1633.5	6.3	2178.0	1694.0	1936.0	29.0
5.	T. 2+*Arachniotus* sp. +*S. atra*	1790.8	1577.84	1684.32	9.6	1984.4	1790.8	1887.6	23.8

TABLE 3. *Residual effect of stimulatory microbes applied to the previous crop (Maize) in May 1981 alongwith chaffed wheat straw (80 kg/acre) amended with 2% N on the yield of wheat crop sown in 3rd week of Dec., 1981*

S. No	Treatment	yield in kgs per acre					Percent increase over control
		RI	RII	RIII	RIV	Average	
1.	Control	1052.7	1161.6	1234.2	929.28	1094.4	–
2.	Chaffed Wheat straw+2% NK	1161.6	1306.8	1270.5	943.8	1170.6	6.9
3.	Chaffed wheat straw+2% N +*Arachniotus* sp.	2105.4	1960.2	1873.08	1669.8	1902.1	73.8

As will be seen from Tables 1 and 2, both the microbes consistantly enhanced the yield of wheat in all the repeats. *Arachniotus* sp. when applied alone showed the best performance. On an average addition of *Arachniotus* sp. along-

with chaffed wheat straw amended with 2 percent NK to the soil enhanced the yield of wheat over control by 39.3 and 24.4 percent in the early and late sown experiments respectively. The activity of *Arachniotus* sp. to increase the yield of wheat was further enhanced when it was added to the soil after being mixed with chaffed wheat straw amended with 4 per cent of its weight of NK. It enhanced the yield of wheat by 42.7 per cent over control against an increase of 24.4 per cent when applied with 2 per cent amendments of NK of chaffed wheat straw. As will be seen from Table 3 the residual effect of *Arachniotus* sp. on the yield of wheat grain yielded spectacular results. It remarkably increased the yield of wheat grain consistently in all the repeats with an average increase of 73.8 per cent, over control. An average yield of the 4 repeats was 1902.1 kg/acre from the treated plots against an average yield of 1094.4 kg/acre from the untreated plots.

2. RICE

An experiment to study the effect of addition of *Arachniotus* sp. alongwith chaffed wheat straw to the soil on the yield of rice paddy was laid out at the Government Agricultural Farm, Sahiwal. The experiment was designed in random blocks with four repeats. The plot size was 200' x 24'. The finely chaffed wheat straw (80 kg/acre) amended with 1 per cent N, as such and after contamination with the suspensions of culture of *Arachniotus* sp. was mixed in the soil during seed-bed preparations before puddling. Transplanting of rice variety Irri-6 was done on 29.6.80. The harvesting of the crop was done on 20.10.80. The yield recorded is given in Table 4.

TABLE 4. *Effect of addition of Arachniotus sp. on the yield of rice paddy.*

S. No.	Treatment	Yield in kilograms/acre				Average	Percent increase over control
		RI	RII	RIII	RIV		
1.	Control	1424	1440	1400	1376	1410	–
2.	Chaffed wheat straw alone + 1%N	1600	1624	1616	1608	1612	14.3
3.	Chaffed/wheat straw + 1%N + Fungal antagonist (*Arachniotus* sp.).	1696	1728	1664	1680	1692	20.0

As will be seen from Table 4 the yield of rice was consistently enhanced in all the repeats with the application of *Arachniotus* sp. alongwith substrate and the substrate alone. Addition of *Arachniotus* sp. alongwith substrate showed the best performance and increased the yield by 20 percent over control.

3. MAIZE

An experiment was designed in random blocks with four replications. Finely chaffed wheat straw amended with 2 percent N used at the rate of 80 kg/ acre as such and contaminated with the culture suspension of the *Arachniotus* sp. was mixed in the soil during the seed bed preparations. It was sown on 8.8.81 with dibler. The spacing from plant to plant and row to row were kept at 1' and 2', respectively. On harvest yield of cobs was recorded separately for each treatment. The results obtained age given in Table 5.

TABLE 5. *Effect of addition of Arachniotus sp. alongwith chaffed wheat straw to the soil on the yield of maize cobs.*

S. No. Treatment	yield in kgs / acre					Percent increase over control
	RI	RII	RIII	RIV	Average	
1. Control	2880	3258.0	2880.0	3420.0	3109.5	–
2. Chaffed Wheat straw+2% NK	2070	3330.0	3060.0	4050.0	3127.2	0.56
3. Chaffed wheat straw+2% N +*Arachniotus* sp.	3330	3510.0	3510.0	3510.0	3465.0	11.40

As will be seen from Table 5, the addition of *Arachniotus* sp. to the soil alongwith chaffed wheat straw amended with 2 percent N enhanced the yield of maize cobs by 11.4 per cent.

4. SUGARCANE

Studies on the effect of addition of *Arachniotus* sp. alongwith finely chaffed wheat straw to the soil to enhance the yield of sugarcane were initiated in 1980. The first experiment as laid out in randomized blocks with four repeats in the area of the Plant Pathologist at Ayub Agricultural Research

Institute, Faisalabad. The plot size was 30' x 10'. Finely chaffed wheat straw (320 kg/a) contaminated with the culture suspensions of *Arachniotus* was mixed in the soil during seed bed preparations. Sowing of sugarcane variety Triton was done on 13.3.1980. The fertilizer was applied in uniform quantity to all the treatments. The experiment was harvested on 31.12.80 and 1.1.81.

Further 3 experiments were conducted during the year 1981-82, at different places. In one experiment the different doses of the substrate i.e. 80 kg/acre, 160kg/acre and 320 kg/acre were used and the substrate was amended with 2 percent of its weight of N. This experiment was laid out at Agricultural Research Station Khanpur with variety L 116. It was designed in random blocks with 4 repeats. The fertilizer and all other operations were applied uniformly to all the treatments. In the other two experiments conducted during this year, the substrate (chaffed wheat straw) amended with 2 percent N was used at the rate of 80 kg/acre. One of these experiments was sown with variety CO 564 at GLC-Wala, Tehsil Khanpur and the second was sown at Faisalabad variety Col. 54 in the area of Agronomy Department of the University of Agriculture, Faisalabad. The observations recorded on the yield of stripped cane are presented in Table 6-9.

As will be seen from Tables 6-9, in all the experiments the application of *Arachniotus* sp. to the soil along with caffed wheat straw consistantly enhanced the yield of sugarcane, irrespective of the varitey and place. The dose of the substrate @ 80 kg/acre amended with 2 per cent of N showed the best performance (Table 7). The increase in yield of stripped cane with the use of *Arachniotus* sp. ranged from 26.9 per cent to 38.8 per cent in the differnt experiments.

TABLE 6. *Effect of addition of Arachniotus sp. on the yield of sugarcane variety Triton at AARI, Faisalabad, (1980-81).*

S. No.	Treatment	yield in kg /acre					% increase
		R I	R II	R III	R IV	Average	
1.	Control	26.24	24.797	21.786	20.522	23.088	—
2.	Chaffed wheat straw	28.892	23.103	25.211	16.531	24.185	4.74
3.	Chaffed wheat straw + *Arachniotus* sp.	32.704	38.478	27.508	26.509	31.320	35.65

As will be seen from the Table the yield of sugar cane was consistantly enhanced with the application of *Arachniotus* sp. in all the repeats. The average increase in yield was 35.65 per cent.

TABLE 7. *Effect of addition of Arachniotus sp. to the soil alongwith chaffed wheat straw on the yield of sugarcane variety L 116 at Khanpur A.R.S. (1981-82)*

S. No.	Treatment	yield in tons / acre R I	R II	R III	R IV	Average	Increase over control
1.	Control	38.51	47.36	50.61	35.93	43.0	—
2.	Chaffed wheat straw @ 320 kg/a + 2% N	51.50	55.31	49.08	50.67	31.6	20.0
3.	Chaffed wheat straw @ 320 kg/a + 2% N + *Arachniotus* sp.	50.14	53.42	52.06	56.21	54.1	25.8
4.	Chaffed wheat straw @ 160 kg/a + 2% N + *Arachniotus* sp.	48.25	56.69	51.92	57.17	53.4	24.1
5.	Chaffed wheat straw @ 80 kg/a +2% N + *Arachniotus* sp.	50.12	55.38	64.71	57.73	56.9	32 3

TABLE 8. *Effect of addition of Arachniotus sp. to the soil alongwith chaffed wheat straw (80 kg/acre) amended with 2 per cent N, on the yield of sugarcane variety COL 54 at University of Agriculture, Faisalabad (1981-82)*

S. No.	Treatment	yield in tons / acre R I	R II	Average	Percent increase over control
1.	Control	33.48	38.16	35.82	–
2.	Chaffed Wheat straw+2% N	43.20	34.56	38.79	8.0
3.	Chaffed wheat straw+2% N +*Arachniotus* sp.	55.62	43.92	49.77	38.8

TABLE 9. *Effect of addition of Arachniotus sp. to the soil alongwith chaffed wheat straw on the yield of sugarcane variety CO 564 at G.U.-W.I.L.I., Tehsil Khanpur (1981-82)*

S. No.	Treatment	Yield in tons/acre RI	RII	RIII	RIV	Average	Percent increase over control
1.	Control	25.41	23.39	27.76	22.68	24.86	–
2.	Chaffed wheat straw + 2% N	31.39	26.13	31.03	28.13	29.18	17.2
3.	Chaffed wheat straw + 2% N + *Arachniotus* sp.	29.94	30.12	35.28	31.03	31.58	26.9

5. BERSEEM

An experiment to study the effect of stimulatory microbes on the yield of Berseem fodder was laid out in random blocks with three repeats. The plot size was 24' x 45'. The treatments applied were the same as described above under experiment No. 1 on wheat crop. The sowing of the crop was done on 8-10-81. All the treatments were harvested simultaneously and the yield of each treatment was recorded separately. In all four cuttings were harvested. The observations recorded are presented in Table 10.

TABLE 10. *Effect of addition stimulatory microbes to the soil alongwith chaffed wheat straw (80 kg) per acre amended with 2 per cent NK on the yield of Berseem fodder*

S. No.	Treatment	yield in tons / acre R I	R II	RIII	Average	Percent increase over control
1.	Control	25.8	24.5	22.4	24.2	–
2.	Chaffed wheat straw + 2% NK	27.2	26.0	27.9	27.0	11.5
3.	T.2 + *Arachniotus* sp.	32.0	33.8	30.6	32.1	32.7
4.	T. 2 + *S. atra*	28.8	28.9	26.1	27.9	15.2
5.	T. 2 + *Arachniotus* sp. + *S. atra*	29.0	29.6	25.8	28.1	16.1

As will be seen from the Table both the microbes increased the yield of the fodder appreciably. *Arachniotus* sp. showed the best performance, as it enhanced the yield of fodder, by 32.7 per cent over control.

DISCUSSION

The present study indicates that, given a suitable substrate, antagonistic organims may exert sufficient action in the soil to produce some organic compounds which ultimately result in enhancing the growth and yield of the crops. Both the stimulatory organisms i.e. *Arachniotus* and *S. atra* when applied to the soil alongwith chaffed wheat straw during seed bed preparations considerably enhanced the yield of crops. *Arachniotus* sp. showed better performance than *S. atra* and its effect was more pronounced when it was applied alone, than when applied in combination with *S. atra*. (Tables 1, 2 and 10). Addition of *Arachniotus* sp. to the soil alongwith chaffed wheat straw amended with N gave better response than when applied with unamended chaffed wheat straw (Tables 6 and 8). Amendment of the substrate with higher concentrations of NK (4 per cent) further improved the action of *Arachniotus* sp. and gave more than the treatments where amendment of substrate with lower concentrations (2 per cent NK) were used (Table 2). Results of the experiment on the dose of the substrate indicate that the chaffed wheat straw when used at lower rate i.e. 80 Kgs/acre gave better results than when used at a higher rates i.e. 320 and 160 kg/acre (Table 8). Studies on the residual effect of *Arachniotus* sp. yielded spectacular results and gave an average increase of 73.8 per cent in yield of wheat (Table 3).

The addition of chaffed wheat straw alone with or without amendments also enhanced the yield of crops in some repeats and reduced it in other repeats (Tables 1, 2, and 6). It would seem to be due to the fact that the soil microflora varies in various patches, the repeats where stimulatory microflora was prevalent the yield was enhanced and where it was lacking the yield was reduced. Seed inoculations with "Azotogen" *(Azotobacter chroococcum)* has been reported to enhance the yield of various crops (Balis, 1946; Alexender, 1961; Meishustin *et al.*, 1963 and Hussain 1975). This increase has been attributed partly due to the fixation of atmospheric nitrogen and partly due to the production of growth stimulents (Mishustin, 1970). The stimulatory or antagonistic microorganisms

decompose the organic substrates in the soil and give rise to certain organic compounds which act as growth hormones or antibiotics. The availability of organic carbon and nitrogen in the soil is known to affect the yield of such organic compounds or antibiotics (Wright 1954, 1956, Mishustin 1970, Akhtar 1977, 1980). In the present studies better crop yields in the treatments with amended substrates would seem to be due to the better production of the organic compounds by the antagonistic organisms. These results indicate that the enhancing of the yield was directly co-related with the decomposition of the organic substrate and production of the organic compounds. Higher increase in the yield of wheat sown after maize due to the residual effect of *Arachniotus* sp. applied to the soil before sowing of maize would seem to be due to the more through decomposition of the substrate in comparatively longer duration consequently leading to the increased production of the stimulatory substance in the soil. The antibiotic produced by the *Arachniotus* sp. is known to supress the activity of the soil borne fungal pathogens and some plant parasitic nematodes (Akhtar 1980, 1981). Whether the increase in crops yield was caused due to supression of soil borne plant pathogens, or through enzymic action of certain enzymes produced by the antagonists, or due to the direct stimulation of the crops growth by the organic compound produced as a result of interaction of the antagonistic organisms and the organic substrates, is a question which requires further investigations for the correct answer. However, the present studies do indicate that the yield of crops can be significantly increased through the use of certain fungal microorganisms. Further investigations to confirm and elaborate the present findings may end up with achievements of revolutionary dimensions in agriculture.

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