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PRODUCTIVITY OF RICE-WHEAT SYSTEM IN RELATION TO *AZOLLA* GREEN MANURE FERTILIZED WITH NITROGEN AND PHOSPHORUS

M Sharif Zia, M Salim, Arshad Ali* and Rahmatullah

Land Resources Research Institute, National Agricultural Research Centre, Park Road, Islamabad, Pakistan

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Nitrogen contribution of *Azolla* fertilized with nitrogen (N) and phosphorus (P) in rice- wheat sequence was investigated in a greenhouse study. Rice yield was significantly increased over control when 100 mg N kg^{-1} soil alongwith 12 and 24 mg P kg^{-1} soil was applied in the absence of *Azolla* green manuring. The rice straw yield was significantly increased at both 50 and 100 mg N kg^{-1} soil over control. *Azolla* green manure increased both the straw and grain yield significantly ($P< 0.05$) at all levels of N and P application. Total N uptake followed the trend observed for straw and grain yield. The 50-12 mg N-P kg^{-1} soil alongwith *Azolla* green manure contributed 2 % of the total N to rice whereas by doubling the P application rate, N contribution increased to 50%. However, application of 100-24 mg N-P kg^{-1} soil, the relative N contribution by *Azolla* sharply decreased to about 30 %. The highest residual N content in soil was observed where 100-24 mg N-P kg^{-1} soil and *Azolla* green manure was applied. However, the highest P content of soil was observed which received 50-24 mg N-P kg^{-1} soil. The residual effect of applied N and P and *Azolla* green manuring significantly increased straw and grain yield of wheat in soil where 50-12, 50-24 and 100-24 mg N-P kg^{-1} soil were applied to rice crop as compared with control.

Key words: Rice-wheat system, *Azolla* green manure, Nitrogen fertility.

Introduction

Nitrogen fertility of soil is a very essential and important determinant for rice production in Pakistan. About 63 % of the N taken up by rice originates from the native soil organic reserves (Ando and Shoji 1985). But Pakistani soils are generally low in organic matter, hence are poor in N fertility. Integrated management of organic manures and inorganic fertilizers can contribute to an increase in N content of rice soils, long term productivity and ecological sustainability.

Use of *Azolla* as a green manure in flooded rice ecosystem is one of the means of fixing atmospheric N through the symbiotic association of *Azolla* with blue green algae. *Azolla* has a unique ability to multiply rapidly and fix atmospheric N, at a comparable rate to most tropical and subtropical legumes (FAO 1980; Watanabe *et al* 1997). Beneficial effect of *Azolla* as green manure in rice field is well documented (FAO 1980). Watanabe *et al* (1997) reported that *Azolla* incorporation increased grain yield up to 25 % over the control. Further efforts to increase the N contained in rice grains through the use of *Azolla* are underway (Ito and Watanabe 1985; Watanabe *et al* 1980; 1988).

*Author for correspondence.

In Pakistan little attention has been given to economize N through the use of *Azolla* in rice as high temperature during the rice season does not permit the growth of *Azolla* in the major rice growing areas of Punjab and upper Sind. But in the northern areas of NWFP and lower Sind, climatic conditions are quite conducive for its growth, therefore, it can help to economize the use of artificial fertilizers. The effects of fertilizer N and P and *Azolla* on rice yield and residual N availability in soil are reported in this paper.

Materials and Methods

The experiment was conducted in a greenhouse at National Agricultural Research Centre, Islamabad, Pakistan, in plastic pots using 5 kg soil of Gujranwala soil series (Udic Haplustalfs). The soil had a pH 7.7, total N 0.04 %, $NaHCO_3$-P 7.10 mg kg^{-1} soil, available K 105 mg kg^{-1} soil and silty clay loam texture. There were eight treatments stated as below:

T_1 = Control (no *Azolla* and no N-P used)
T_2 = 50 mg N kg^{-1} soil
T_3 = 50 mg N and 12 mg P kg^{-1} soil
T_4 = 50 mg N, 12 mg P kg^{-1} soil and *Azolla* green manure

T_5 = 50 mg N and 24 mg P kg^{-1} soil
T_6 = 50 mg N, 24 mg P kg^{-1} soil and *Azolla* green manure
T_7 = 100 mg N and 24 mg P kg^{-1} soil
T_8 = 100 mg N, 24 mg P kg^{-1} soil and *Azolla* green manure

All N as urea and P as diammonium phosphate were applied in solution form. Zinc as zinc sulphate was applied @ 25 mg Zn pot^{-1} to all the treatments and was incorporated in the previously flooded soil. *Azolla* (*Azolla pinnata*) was applied 5 times @ 200 g (fresh weight) pot^{-1} during growth period after every two weeks. The experiment was laid out in completely randomized design using three replications. Three 15 day old nursery plants (var. KS-282) were transplanted to each pot. Crop was harvested at maturity. Productive tillers $plant^{-1}$, straw and grain yields were recorded. Soil samples were collected after rice harvesting. The soil samples were analyzed for N (Kjeldahl-N) (Bremner and Mulvaney 1982) and P ($NaHCO_3$). Plant samples were also analyzed for N (Bremner and Mulvaney 1982). After the harvesting of rice crop, 5 plants pot^{-1} of wheat (var Pak-81) were grown in the same pots to assess the residual effects of *Azolla* and applied fertilizers on the succeeding crop. Grain and straw yield of wheat were recorded at maturity.

The data thus collected were analyzed using analysis of variance and LSD at 5 % probability level to test the significance of the treatment means.

Results and Discussion

Both straw and grain yield of rice responded significantly to various treatments (Table 1). With the application of 50 mg N kg^{-1} soil (T_2), straw yield increased significantly over control but grain yield did not. Supplementing either 12 or 24 mg P kg^{-1} soil with 50 mg N kg^{-1} soil application did not further improve straw yield. Enhancing N application to 100 mg kg^{-1} soil significantly increased straw and grain yield. At each level of N and P application, *Azolla* green manuring significantly increased ($P < 0.05$) both the straw and grain yield of rice. Similar results have been reported by Kolhe and Mitra (1987) and Kumarasinghe and Eskew (1993). For various levels of N and P application, *Azolla* green manuring resulted in significantly higher N uptake by rice plants. Mian and Stewart (1985) observed 34 %, recovery of *Azolla*-N by 60 days old rice plants.

The increase in total N uptake was only 50 mg pot^{-1} (T_2-T_1) compared with the 250 mg N pot^{-1} applied, which indicates a 20% recovery of N applied as fertilizer (Table 1). It may be due to enhanced losses of inorganic N under flooded ecosystem. But on the other hand AGM (*Azolla* green manuring) is a N fixer which fixes N throughout the growing period for crop utilization. That is why N uptake by plants from T_4, T_6 and T_8 is exceptionally higher as compared with the treatments receiving N from inorganic sources.

The increase in N uptake was enhanced only slightly (10 mg N pot^{-1}) by the application of 60 mg P pot^{-1} as compared with control and the increase in N uptake was 30 mg N pot^{-1} when 120 mg P pot^{-1} was applied as compared with 60 mg P pot^{-1}. There is a synergestic effect of N or P on each other. However, Pakistani soils are mostly calcareous alkaline in reaction with pH around 8 which is a very favourable condition for P fixation (Rahmatullah *et al* 1994). Hence little P in soil solution under such conditions is not sufficient for dramatic effect on N utilization by plants.

The interaction between N and P was much stronger at a higher level (T_7-T_3) than at lower level (T_3-T_1) (Table 1). The data did not reveal a stronger interaction between N and P at lower level of P. However, at higher level of P application,

Table 1
Influence of nitrogen and phosphorus fertilization (N-P mg kg^{-1} soil) and *Azolla* green manure (AGM) on rice yield

	Treatment	Straw yield (g pot^{-1})	Grain yield (g pot^{-1})	Total N uptake (mg pot^{-1})	Increase in N uptake over control (mg pot^{-1})
T_1	Control	22c	17e	240d	-
T_2	50-0	30b	21de	290cd	50
T_3	50-12	28b	24cd	300cd	60
T_4	50-12+AGM	38a	39b	360c	120
T_5	50-24	27b	27c	320c	80
T_6	50-24+AGM	36a	38b	480b	240
T_7	100-24	36a	35b	440b	200
T_8	100-24+AGM	40a	47a	585a	345

the interaction is quite strong. It is inferred that P applied in the present study is insufficient to meet the high P requirement of KS-282 variety of rice.

At 50-12, 50-24 and 100-24 mg N-P kg^{-1} soil application, the relative contribution of N to rice by *Azolla* green manuring is presented in Fig 1. With the application of 50-12 mg N-P kg^{-1} soil, *Azolla* green manuring contributed 60 mg N pot^{-1}. Whereas by doubling the P application rate, this value sharply increased to 160 mg N pot^{-1} which indicates an improved efficiency of *Azolla* in contributing N to rice crop. However, keeping the P application at 24 mg kg^{-1} soil and increasing the N application from 50 to 100 mg kg^{-1} soil, the relative N contribution by *Azolla* sharply decreased to 145 mg N pot^{-1}. These observations provide some indication of soil available N and P levels for the maximum efficiency of *Azolla* to contribute N to growing rice crop (Singh and Singh 1987). It can be observed from Table 1 that the effect of AGM in improving total N uptake increased dramatically (from 60 to 160 mg pot^{-1}) when the amount of P increased from 60 to 120 mg pot^{-1}, but the increase was slightly lowered by the use of larger dosage of N fertilizer. The latter point suggests that the N_2-fixation activity of *Azolla* was not much affected by the presence of an increased dosage of N fertilizer, at the level tested. The reason might be the significant magnitude of N losses under flooded conditions at higher level of N application. Therefore, the usually expected depressive effects of inorganic N application on N fixation by *Azolla* was obscured.

After the rice harvest, N and P content of the soil receiving various N, P and *Azolla* green manuring treatments had increased to variable degrees (Table 2). The highest N content was observed in soil receiving 100-24 mg N-P kg^{-1} soil and

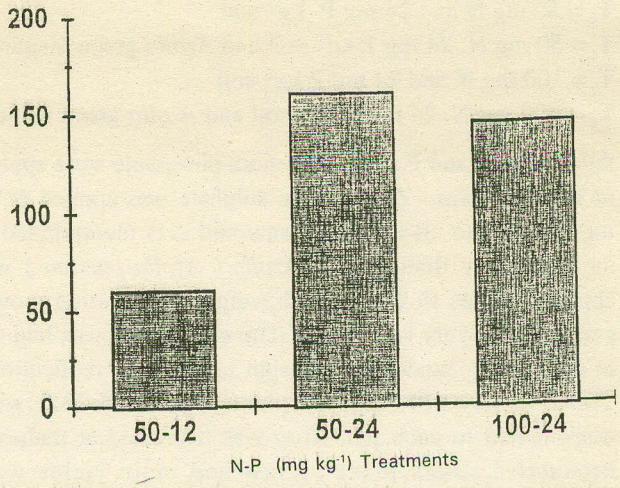

Fig 1. Influence of applied nitrogen and phosphorus on nitrogen contribution of *Azolla* green manure to N uptake by rice.

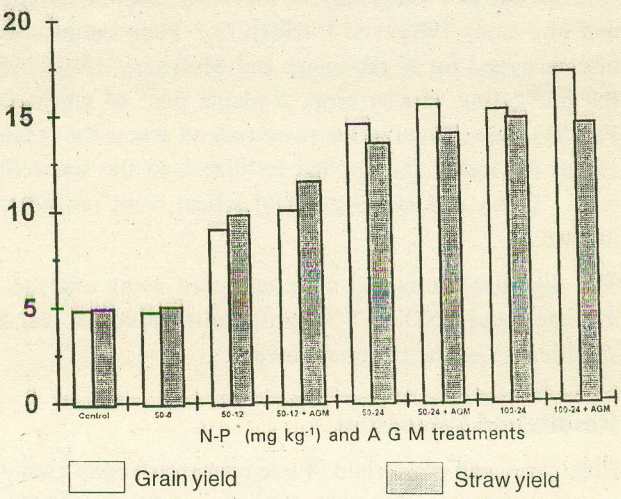

Fig 2. Residual effect of nitrogen and phosphorus fertilizers and *Azolla* green manuring on wheat yield.

Table 2

Effect of fertilizer treatments (N-P mg kg^{-1} soil) and *Azolla* green manuring (AGM) on total N and available P contents of soil

	Treatment	Total N (mg kg^{-1})	N increase over control (mg kg^{-1})	$NaHCO_3$-P (mg kg^{-1})	P increase over control (mg kg^{-1})
T_1	Control	450	-	6.85f	-
T_2	50-0	460	10	6.78f	-
T_3	50-12	460	10	7.25e	0.47
T_4	50-12+AGM	520	70	6.98f	0.20
T_5	50-24	470	20	9.64a	2.86
T_6	50-24+AGM	530	80	9.18b	2.40
T_7	100-24	500	50	8.85c	2.07
T_8	100-24+AGM	540	90	8.50b	1.72
	LSD (0.05)			0.23	

Azolla green manure which shows the beneficial effect of *Azolla* on improving N fertility of soil. However, the highest P content of soil was observed in treatment receiving 50-24 mg N-P kg^{-1} soil. It appears that at this N-P application level, comparatively lower straw and grain yield resulted in higher amount of unused P in soil. It can be seen from Table 2 that the increase in total N content in the soil was only slightly increased by a N fertilizer dosage of 100 mg kg^{1}, being 10 mg kg^{-1} (T_2-T_1, T_3-T_1) or 20 mg kg^{-1} (T_5-T_1). But the increase was larger (50 mg kg^{-1}) when 100 mg N kg^{-1} was applied. These results and the uptake of N by plants indicated that much of the N applied was lost. In Pakistan, rice is grown under flooded conditions. Most of the soils are alkaline calcareous with pH about 8. Chemistry of N and P under flooded conditions is entirely different than that under upland conditions. Anaerobic and saturated conditions of rice fields are helpful for leaching and denitrification losses of applied N. Whereas P solubility is reduced by alkaline soil reaction and P is precipitated to insoluble forms of calcium phosphate under calcareous conditions (Sikander *et al* 1998).

Straw and grain yields of wheat grown in the same soil after rice harvest are presented in Fig 2. The residual effects of applied N, P and *Azolla* green manuring appear to be remarkable. Significantly higher straw and grain yields of wheat were observed in soil where 50-12, 50-24 and 100-24 mg N-P kg^{-1} soil were applied to the previous crop as compared with control and 50 mg N kg^{-1} soil treatment. It is important to note that wheat grain yield increased consistently by *Azolla* green manuring at all levels of N-P application. Kolhe and Mitra (1987) reported 63 % wheat yield increase as a result of residual effect.

Results of this study highlight the beneficial role of *Azolla* in improving the efficiency of applied N and P fertilizers for rice as well as enhancing the N-P fertility of soil. The improved N-P status of soil ultimately enhances the yield of succeeding wheat crop.

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