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WHEAT GROWTH AND YIELD RESPONSE TO VARIOUS GREEN MANURE LEGUMES AND DIFFERENT P LEVELS IN POTHOWAR REGION

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A long term field study was conducted to investigate wheat growth and yield response to various green manure legumes (Sesbania, Cluster bean, Rice bean) and different P levels (0, 30, 60, 90 kg P_2O_5 ha^{-1}). There was a significant but variable effect of incorporation of various green manure legumes on wheat growth and yield. Maximum total biomass was produced by Sesbania incorporation followed by Cluster bean and Rice bean in descending order. Similar trend was observed in case of grain yield under these treatments. Application of P, further improved the wheat biomass production as well as grain yield of wheat. Increasing dose of P (30, 60 and 90 kg P_2O_5 ha^{-1}) increased the yield by 10, 26 and 40% over control. Over all, average residual effect of green manure crops alongwith various doses and time of P application was consistent and significant. Green manuring alone had 9% residual effect whereas P application caused a residual effect of 14% on the following wheat crop.
Keywords: Legume green manures; P application; wheat; growth and yield; rainfed conditions

INTRODUCTION

Increasing population pressure and food demand of the people combined with reduction in productive agricultural lands in Pakistan are forcing farmers of rainfed agro-ecosystems to adopt more intensive farming systems. Farmers have responded to these pressures by growing more cereals. Consequently, it has led to gradual deterioration of natural resource base and accelerated exhaustion of soil nutrient reserves (Salim *et al.* 1987; Azad *et al.* 1993). This rapid nutrient depletion has caused serious threats to overall agricultural productivity of rainfed areas of Pakistan including Pothowar Plateau. On the other hand, the present agricultural production practices are contributing in the environmental degradation and thus destabilizing the natural resource base in Pakistan in general and in rainfed areas in particular. The prevailing farming system of Pothwar Plateau depends predominantly on the rainfed wheat, barley, sorghum, millet, maize and rape-seed. The soils of the Pothowar Plateau are low in fertility especially in N, P and organic matter. Moreover, the recent trend for growing continuous cereals on all arable lands has further depleted the nutrients in the soils which are already low (Rashid and Qayyum, 1991). Consequently, use of inorganic fertilizers has become important for successful crop production in rainfed areas of Pothowar Plateau. However, with the use of expensive inorganic fertilizers, the cost of crop production has substantially increased. It is, therefore, important to promote economically viable and environment friendly interventions for sustainable agriculture in rainfed farming system of Pothowar Plateau.

Green manuring by forage legumes has the potential to integrate in the present farming system of Pothowar region. Legumes grown in low fertility soils could improve the soil health by fixing atmospheric N and may partially supplement the use of inorganic fertilizers. Legumes may also improve the production of cereal crops by adding much needed organic matter in the soils and by improving physical properties of soils. Beneficial residual effects of legumes have been largely responsible in sustaining soil fertility and saving inorganic fertilizers in subsequent non-legume crops. Mahler and Auld (1989) observed that incorporation of peas, green manure crop and their residues after harvesting grains significantly increased subsequent wheat grain yield. The corresponding N fertilizer equivalents were 94 and 75 kg N ha^{-1}. Forage legumes contribute substantial amount of N in the soil and, therefore, have a positive residual effect on the grain and straw yield of the subsequent cereal crops (Bouldin, 1988; Rinaudo *et al.* 1988). In addition, application of a basal dose of P was reported to have a significant positive effect on the growth and biological yield of the legumes (ICARDA, 1993). It has been estimated that substantially higher yield from cereals can be expected if grown after green manuring crops. Nitant (1990) reported that *Leucaena loppins* for example, applied as green manure significantly increased the grain yield of wheat over control. He further reported an increase in sorghum yield as a result of green manuring. There are, however, a number of factors affecting biological N fixation and subsequent residual N that vary with crop, site, season and cropping sequence. Annual forage legumes such as Sesbania, Cluster bean and Rice bean, if used as

green manures, will improve the productivity of soil and the succeeding crop (Ibrahim *et al.* 1999). These forage legumes have the potential to be included in the present farming systems of Pothowar for improving soil fertility and increasing crop productivity. Hence, there was a need to investigate and evaluate maximum potential of these forage legumes and their residual effects on soil fertility and crop productivity with green manuring and P fertilization. Green manure therefore, seems particularly attractive for farmers on marginally productive soils, at least as a strategy to improve yield and yield sustainability (Diekmann *et al.* 1996). The present study was thus conducted to quantify the effects of P fertilizer and its sequencing on green manure yield of legumes and monitoring the productivity of succeeding wheat crop.

MATERIALS AND METHODS

The study was conducted at the experimental area of Forage and Pasture Program of National Agricultural Research Centre, Islamabad. The centre lies in a sub-tropical, sub humid continental highland climatic zone characterized by hot long summers and cold winters. Soil of the field under study was Inceptisol and loess in nature, slightly alkaline with pH 8.2 but low in organic matter (0.5%), total N 0.09% and P 6.3 $\mu g\ g^{-1}$ of soil.

The green manure legumes viz. i) Sesbans, *Sesbania aculeata* (Linn), ii) Ricebean, *Vigna umbellate* (Thunb), and iii) Cluster bean, *Cyamopsis tetragonaloba* L. were used as green manure crops. Wheat variety Inqalab-91 *Triticum aestivum* L. was sown as succeeding cereal crop. The study comprised of two experiments. Each experiment was conducted according to two factors Randomized Complete Block Design (RCBD) with four replications. The factors used were Green manures and P fertilization. The treatments were as:

T1 = Fallow
T2 = Fallow + P_2O_5 @ 30 kg ha^{-1}
T3 = Fallow + P_2O_5 @ 60 kg ha^{-1}
T4 = Fallow + P_2O_5 @ 90 kg ha^{-1}
T5 = Cluster bean
T6 = Cluster bean + P_2O_5 @ 30 kg ha^{-1}
T7 = Cluster bean + P_2O_5 @ 60 kg ha^{-1}
T8 = Cluster bean + P_2O_5 @ 90 kg ha^{-1}
T9 = Rice bean
T10 = Rice bean + P_2O_5 @ 30 kg ha^{-1}
T11 = Rice bean + P_2O_5 @ 60 kg ha^{-1}
T12 = Rice bean + P_2O_5 @ 90 kg ha^{-1}
T13 = Sesbania
T14 = Sesbania + P_2O_5 @ 30 kg ha^{-1}
T15 = Sesbania + P_2O_5 @ 60 kg ha^{-1}
T16 = Sesbania + P_2O_5 @ 90 kg ha^{-1}

The land was ploughed with double disc to prepare a suitable seed bed. The legumes were sown by hand drill with row to row distance of 40 cm. Seed rate was 50 kg ha^{-1} for Sesbania, 80 kg ha^{-1} for Ricebean and 50–55 kg ha^{-1} for Cluster bean. Different forage legumes were incorporated at blooming stage i.e. 60 days after their establishment. The tender stem and plants were manually harvested and later chopped and incorporated into the soil by rotavator. Experimental area was ploughed twice by double disc and finally cultivated and planked to prepare a suitable seed bed for the sowing of wheat crop using seed @ 100 kg ha^{-1}. Data regarding productive tillers, total biomass and grain yield ($1m^2$ quadrat) were collected at maturity. Plant samples colleted were digested in 20 ml HNO_3 (conc.) and 10 ml Perchloric acid (72%). Colour was developed by ammonium vanadate and molybdate whose intensity was measured by Bausch and Lomb Spectronic 20 and was used for estimating P concentration in the plant material. Phosphorus uptake in the plant material was calculated by multiplying the P concentration in the plant material with the plant dry matter (Shiou Ktio, 1996).

The data was analyzed statistically using Randomized Complete Block Design factorial. A software package MStat C was used for ANOVA. Significant differences in selected crop growth and yields, and soil physical properties attributed to the main and interactive effects of green manures and P levels at two different depths of soil were analyzed using an ANOVA procedure of the MStat-C software. Treatment means were separated by using a F-protected DMRT at $P>0.05$. The differences among treatment means at $P< 0.10$ were considered trends.

RESULTS AND DISCUSSION

The effect of various grean manure crops and application of P was studied on the following wheat crop. The results obtained were as:

Number of Tillers

Among individual green manure crops, Sesbania and Cluster bean increased tillering by about 16% and 11% respectively, over control. Phosphorus applications to green manure crops caused a slight improvement in tillering and enhanced inter species variation but was statistically non-significant. Interaction of green manure crops and P application showed non-significant effect on tillering capacity of wheat grown during the study period. Maximum number of tillers per plant were recorded where P was applied 90 kg ha^{-1} closely followed by 60 kg ha^{-1} with various legume crops.

Effect of P application was significant whereby 27% increase in tillering was observed by 90 kg P ha^{-1} whereas 60 P kg ha^{-1} increased 17% number of tillers over control.

It was quite probable that incorporation of green manures facilitated the absorption of added P that might have caused significant improvements in tillering. In cereals, tillering is affected inversely due to P deficiency. Thus not only low yields but also poor quality grains are obtained from P deficient crops (Khasawanch *et al.* 1980; Sarir *et al.* 1992). Plant roots play a considerable role in solubilization of phosphorus. Due to phosphates activity of root cell walls, the rate of organic P turnover is much higher in the rhizosphere than in the bulk soil. This activity of roots utilizes more phosphorus and improves tillering. Similar conclusions had also been drawn by Bieleski (1973) and Nair and Mengel (1984). The combination of incorporating green manures and P applied to wheat crop provides ideal conditions for wheat crop germination and to improve tillering capacity of wheat as the addition of green manures and inorganic P improves soil physical health and legumes supplied N released to plants they need. The N_2 fixed by legumes and N derived from organic material by mineralization improved the N use efficiency and consequently improved the tillering capacity of wheat cultivated after incorporation of green manure legume crops. Tillering is an important growth characteristic directly linked with the productive potential of the plant in terms of biomass (straw and grain) yields. It is attributed to the stronger role of green manure in improving tillering capacity. Hussain and Ibrahim (1987) and Khan *et al.* (2001) have also documented similar conclusions.

Total Biomass (t. ha^{-1})

The results presented in Table 2A clearly indicate significant but variable effects of incorporation of various green manure crops on total biomass production of grain and straw yields of wheat crop. Maximum production of total wheat biomass, for example, was 7.64 t ha^{-1} (16% rise) with Sesbania incorporation followed by 7.32 t ha^{-1} (11%) with Cluster bean and 7.02 t ha^{-1} (7%) with Rice bean. Similarly, wheat grain yields (Table 3A) are 2.90 t ha^{-1} with Sesbania (19 % rise), 2.73 t ha^{-1} (12%) with Clusterbean and 2.63 t ha^{-1} (about 8% rise) with Ricebean. Figures for straw yields (Table 4A) are 4.74 t ha^{-1} (about 15% rise), 4.58 t ha^{-1} (11%) and 4.39 t ha^{-1} (6%) for Sesbania, Clusterbean and Ricebean respectively. These results are in agreement to those reported by Akram *et al.* (1982) and Khan *et al.* (1996), they reported marked increase in wheat yield by applying organic and inorganic manures. Similarly Nahar *et al.* (1995) reported that grain yield of wheat was 1.33 t ha^{-1} in control and 2.62 t ha^{-1} in plots where compost (rice straw + cattle manure) was previously incorporated. Application of Ipil Ipil leaves as green manure and cattle manure during the previous rice crop increased wheat yield to 1.98 and 2.2 t ha^{-1}, respectively. Zia *et al.* 1992 reported that the maximum wheat grain yield was obtained with the application of FYM + 50% recommend NPK, which produced a significantly greater yield than the application of 100% NPK. The results reported by Gaur *et al.* (1973; 1995) substantiated these results of present investigations that conformed differential but positive effects of incorporating residues of various crops on succeeding crop yields. They reported in their studies that legume crops residues took much shorter time for their decomposition and thus resulted increased benefit to the succeeding crops.

Effect of Phosphorus on Total Biomass of Wheat

Results given in Table 2A show that application of 90 kg P_2O_5 ha^{-1} to green manures caused 8.40 t ha^{-1} (40% increase over control) in total biomass production as compared to 7.55 t ha^{-1} (26% increase over control) for 60 kg P_2O_5 ha^{-1} and 6.61 t ha^{-1} (10% increase over control) for 30 kg P_2O_5 ha^{-1}. Similarly, on an average, an increase of about 42%, with 90 kg P_2O_5 ha^{-1}, 27% with 60 kg P_2O_5 ha^{-1} and 13% with 30 kg P_2O_5 ha^{-1} over control was noted in grain yield (Table 3A). These results were a clear indication of beneficial effects of increasing P supply for further enhancing wheat yields under continuous cropping in Pothwar region. It may be noted that the current high yielding wheat varieties have a much higher demand for P. If P supply to such crops becomes inadequate especially during the early stages of their development due to low P-reserves or its delayed release it results in serious set back to crop yields. Hence these crops respond positively to P application. As P enhance root development and the healthy roots absorb more nutrients from rhizosphere. Water use efficiency is also increased due to which healthy crop stand is resulted. Further, the use of legume crops caused a beneficial effect on soil fertility and on succeeding crop as well (Zia *et al.* 1992; Nahar *et al.* 1995; Ahmed *et al.* 2002).

These finding are supported by Pillai (1985), who observed wheat response to P application at various locations and reported significant yield increase as well. The results of Saggar *et al.* (1985) and Azad *et al.* (1993) also confirmed results described above by reporting that wheat crop responded significantly in soils which were low in available phosphorus in Gurdaspur district of Indian Punjab.

Interaction of Green Manure Legumes and P Fertilization on Total Biomass

There was a positive interaction of Green Manuring crop with P application on total biomass production of wheat (Table 2B). Sesbania for example had a significant increase by 20% at 90 kg P_2O_5 ha^{-1} as well as 12% increase at 60 kg kg P_2O_5 ha^{-1}. Cluster bean on the other hand showed significant positive interaction of 30% and 21% increase at 90 as well as 60 kg P_2O_5 ha^{-1}, respectively, whereas it had only 7% increase at 30 kg P_2O_5 ha^{-1} level. Rice bean however had moderate to mild interactions of 18, 10 and 4% at 90, 60 and 30 kg P_2O_5 ha^{-1} respectively. Similar pattern of interaction was visible with regard to wheat grain (Table 3B) and wheat straw (Table 4B) yields. The present data reveals that maximum grain yields in this farming system was possible by combining Cluster bean or Sesbania incorporation as green manure along with application of 60 or 90 kg P_2O_5 ha^{-1}. It appears that for optimum interaction, one should test higher doses of P with these green manures in this area. These findings are in line with the results of Sahu and Nayak (1971), who studied the effect of inorganic fertilizers in combination with green manures. Salim *et al.* (1987) conducted investigation pertaining to combining of organic and inorganic sources of plant nutrients and inferred that organic source gave better results when applied in conjunction with the inorganic source. Similarly Sarir *et al.* (1992) conducted field experiment to evaluate relative efficiency of phosphatic fertilizers with organic manure on wheat yield; they concluded that wheat yield was significantly more when phosphatic fertilizer was applied in combination with organic manure.

P uptake (kg ha^{-1})

Data in Table 5 indicates that on average basis, there was no significant difference among various green manure legumes as well as with control in terms of their influence on P uptake by succeeding wheat crop. On the other hand, P application significantly enhanced P uptake by following wheat crop during both the years. An increase of 45, 30 and 13% over control in P uptake due to P application @ 90, 60 and 30 kg P_2O_5 ha^{-1}, respectively was observed. Among various green manure crops Sesbania showed better performance with P application @ 60 kg ha^{-1} than other green manures while with increasing P rate (90 kg ha^{-1}) all green manure legume crops were statistically at par even with those plots receiving lower dose.

The probable reason for above P uptake appears to be adequate application of P to the crop either direct to wheat crop or indirect through legume green manure crop. A good crop stand also may be the main factor under these treatments. The efficiency of applied P fertilizer differs with the method of application because P is known to become fixed in many soils. Similar conclusions have also been discussed by Vig and Singh (1983) and Sander and Echball (1988).Transformation of P in soil is believed to be a dynamic process which is influenced by rhizosphere besides other soil and plant characteristics.

Table 1. Number of Tillers as influenced by Green Manure Legumes and different P Levels

Green Manure Legume	P Level (kg ha^{-1})				Mean
	0	30	60	90	
Fallow	256.64 d*	280.39 b-c	296.99 a-d	321.88 a-d	280.95 A
Cluster bean	270.38 cd	292.46 a-d	328.08 a-d	353.53 ab	311.11 A
Rice bean	271.11 cd	284.03 b-d	305.20 a-d	342.80 a-c	300.78 A
Sesbania	288.02 b-e	307.39 a-d	339.12 a-c	364.58 a	324.77 A
Green Manure Mean	276.50 B	294.62 B	324.13 AB	353.63 A	312.22 A
Grand Mean	271.51 B	291.06 B	317.35 AB	345.69 A	304.40 A

*Values followed by same letter(s) are statistically similar at P=0.05 level of significance

Table 2-A. Total Wheat Biomass (t ha^{-1}) as influenced by Green Manure Legumes and different Levels of P.

Green Manure Legume	P Levels (kg ha^{-1})				Mean
	0	30	60	90	
Fallow	5.62 i	6.22 g-i	6.86 eh	7.61 c-e	6.58 B
Cluster bean	5.97 g-i	6.65 f-i	7.84 cd	8.80 ab	7.32 A
Rice bean	5.92 hi	6.56 g-i	7.44 c-f	8.15 a-c	7.02 AB
Sesbania	6.48 g-i	7.01 d-g	8.05 bc	9.05 a	7.64 A
Green Manure Mean	6.12 C	6.74 C	7.77 B	8.67 A	7.33 A
Grand Mean	5.99 C	6.61 C	7.55 B	8.40 A	7.13 A

*Values followed by same letter(s) are statistically similar at P=0.05 level of significance.

Table 2-B. Interaction of Green Manure Legumes with P Applications in relation to Total Biomass of Wheat

Green Manure Legume	P Level (kg ha^{-1})		
	30	60	90
Cluster bean	+ 7 %	+ 21 %	+ 30 %
Rice bean	+ 4 %	+ 10 %	+ 18 %
Sesbania	+ 5 %	+ 12 %	+ 20 %

Table 3-A. Wheat Grain Yield (t/ha^{-1}) as influenced by Green Manuring under different P Levels

Green Manure Legume	P Levels (kg ha^{-1})				Mean
	0	30	60	90	
Fallow	2.06 i	2.31 g-i	2.56 e-g	2.84 c-e	2.44 C
Cluster bean	2.20 hi	2.51 e-h	2.94 c-e	3.28 ab	2.73 AB
Rice bean	2.20 hi	2.51 e-h	2.76 c-e	3.06 bc	2.63 BC
Sesbania	2.40 f-i	2.68 d-f	3.07 bc	3.47 a	2.90 A
Green Manure Mean	2.27 D	2.57 C	2.92 B	3.27 A	2.76 A
Grand Mean	2.22 D	2.50 C	2.83 B	3.16 A	2.68 A

*Values followed by same letter(s) are statistically similar at P=0.05 level of significance.

Table 3-B. Interaction of Green Manure Crops with P Applications in relation to Biomass of Wheat Grain Yield

Green Manure Legume	P Level (kg ha^{-1})		
	30	60	90
Cluster bean	+ 14 %	+ 23 %	+ 33 %
Rice bean	+ 6 %	+ 11 %	+ 17 %
Sesbania	+ 15 %	+ 21 %	+ 27 %

Table 4-A. Wheat Straw Yield (t/ha^{-1}) as influenced by Green Manuring under different P Levels

Green Manure Legume	P Level (kg ha^{-1})				Mean
	0	30	60	90	
Fallow	3.55 i*	3.91 g-i	4.30 eh	4.77 c-e	4.13 B
Cluster bean	3.77 g-i	4.14 f-i	4. 90 cd	5.52 ab	4.58 A
Rice bean	3.71 hi	4.05 g-i	4.69 c-f	5.09 a-c	4.40 AB
Sesbania	4.08 g-i	4.33 d-g	4.98 bc	5.58 a	4.74 A
Green Manure Mean	3.85 C	4.17 C	4.85 B	5.40A	4.57 A
Grand Mean	3.78 C	4.11 C	4.72 B	5.24 A	4.46 A

*Values followed by same letter(s) are statistically similar at P=0.05 level of significance.

Table 4-B. Interaction of Green Manure Crops with P Applications in relation to Biomass of Wheat Straw Yield

Green Manure Legume	P Level (kg ha^{-1})		
	30	60	90
Cluster bean	+ 16 %	+ 22 %	+ 30 %
Rice bean	+ 7 %	+ 8 %	+ 10 %
Sesbania	+ 8 %	+ 12 %	+ 15 %

Table 5. P uptake (kg ha^{-1}) by wheat crop (Straw + Grain) as influenced by Green Manure Legumes and different P Levels

Green Manure Legumes	P Level (kg ha^{-1})				Mean
	0	30	60	90	
Fallow	12.30 c*	15.15 b	17.50 ab	19.54 a	16.12 A
Cluster bean	13.16 c	14.52 bc	17.42 ab	18.68 a	15.95 A
Rice bean	13.58 c	14.68 bc	15.82 b	18.67 a	15.64 A
Sesbania	14.13 bc	15.37 b	18.18 a	20.00 a	16.92 A
Green Manure Mean	13.54 CD	14.86 C	17.14 B	19.11 A	15.64 A
Grand Mean	13.23 CD	14.93 C	17.23 B	19.22 A	15.76 A

*Values followed by same letter(s) are statistically similar at P=0.05 level of significance.

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