Effect of PSB and VAM with different Sources of Phosphatic Fertilizer on Growth Attributes, Chlorophyll Content and Yield of Wheat

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Article History

Manuscript No. 72
Received in 30th November, 2010
Received in revised form 22nd January, 2011
Accepted in final form 21st February, 2011

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Keywords

Phosphatic source, growth attributes, chlorophyll content, yield, wheat

Abstract

Field experiments were conducted during *rabi* seasons of 2002-03 and 2003-04 at Indian Agricultural Research Institute, New Delhi to see the response of various phosphatic sources in the form of chemical fertilizers and biofertilizers on growth attributes, chlorophyll content and yield of wheat (cv. HD 2285). The experimental design of the field experiment was randomized block design. There were twelve treatments where various phosphatic sources were applied either singly or in combination with nitrogen. All these treatments were replicated thrice. The treatment $N_{120}SSP_{30}VAM$ recorded highest leaf area of 224.57 cm^2 $plant^{-1}$ at late jointing stage in 2002-03 while in 2003-04 the leaf area of $N_{120}RP_{30}PSB$ (230.57 cm^2 $plant^{-1}$) was highest. In both the years, the treatments $N_{120}SSP_{30}VAM$ and $N_{120}RP_{30}PSB$ gave statistically at par values for dry matter yield which were higher than all other treatments. At late jointing stage, the highest chlorophyll content of 2.86 mg g^{-1} fresh weight and 2.95 mg g^{-1} fresh weight were observed in $N_{120}SSP_{30}VAM$ in 2002-03 and in $N_{120}RP_{30}VAM$ in 2003-04 respectively and during both the years the values were statistically at par. Due to better leaf area, dry matter and chlorophyll content, the treatments $N_{120}SSP_{30}VAM$ and $N_{120}RP_{30}PSB$ also resulted in higher grain yield, stover yield and harvest index. Thus combined application of VAM with SSP and PSB with RP can give satisfactory growth as well as yield in case of wheat.

1. Introduction

Energy crisis resulted into high price index of chemical fertilizers. Coupled with their limited production, fertilizer cost; soil health, sustainability and pollution have led to a renewed interest in the use of alternative nutrient sources of which use of biofertilizers is worth mentioning. The nutrient requirement of a crop is met by the external application of chemical or biofertilizers as soil amendment, seed/ soil inoculation with biofertilizer or by foliar application. Besides these, a part of the crop nutrient demands is also met by the available soil nutrients. Among the inorganic nutrients, phosphorus besides its function in energy storage and transfer in plants is also associated with root development. A considerable part of soil P is organically bound which is not available form for plant utilization. The largest fraction of organic P appears to be in the form of phytin (inositol-hexaphosphate) and its derivatives (Dalal, 1978). In order to become available to plants, phosphorus compounds must be hydrolysed by a group of enzymes called phosphatases or phytases, which may be of plant or microbial origin. Soil phosphates are rendered available either by plant root or by soil microorganisms through secretion of organic acids. They may also release soluble inorganic phosphates into soil through decomposition of phosphate rich organic compounds. This solubilization of phosphates is dependent on soil pH.

In India, most of the soils are either deficient or marginal in P status. Adequate P fertilization is thus essential for economic and sustained crop production. Phosphorus deficient soils require heavy dose of phosphatic fertilizers which are imported and expensive. Also immediate conversion of water soluble P, due to P fixation result in low fertilizer use efficiency (Mahanta and Rai, 2008). Among the different inorganic P sources, single super phosphate (SSP) is the most widely used phosphatic fertilizers which supply P in water soluble form in the immediate vicinity of roots. Its importance as the most efficient P fertilizer source is well established but it is very expensive and need to be imported. It also suffers from the problem of fixation in the long run. However, India has vast resources of indigenous rock phosphate (RP). Unfortunately most of the RPs of Indian origin have the limitation of low P_2O_5 content and low reactivity and perform poorly when applied directly to neutral soil and are not suitable for manufacture of phosphatic fertilizer. With the discovery of several deposits of RP in the country, interest in the use of this indigenous material as alternative phosphatic fertilizers has increased greatly. In this context, biofertilizers like phosphate solubilizing bacteria (PSB) and vesicular arbuscular mycorrhiza (VAM) can prove effective (Somani, 2005). The phosphate solubilizing bacteria releases organic acids in the rhizosphere which decreases the rhizosphere pH and helps in dissolution of insoluble and fixed form of P thus rendering them available to the plant. On the other hand, the role of VAM in the acquisition of immobile nutrients like P from the soil has been long recognized and well documented. Thus an attempt has been made to study the impact of various phosphatic sources on the growth attributes, chlorophyll content and yield of wheat

2. Materials and Methods

A field experiment was carried out during *Rabi* season of 2002-03 and 2003-04 at IARI farm, New Delhi. The experiment was laid out in randomized block design (RBD) with twelve treatments and three replications. The twelve treatments were - T_1: Single Super Phosphate @ 60 kg P_2O_5 ha^{-1} (SSP_{60}); T_2: Rock Phosphate @ 60 kg P_2O_5 ha^{-1} (RP_{60}); T_3: Urea @ 120 kg N ha^{-1} (N_{120}); T_4: : Urea @ 120 kg N ha^{-1} + Single Super Phosphate @ 60 kg P_2O_5 ha^{-1} ($N_{120}P_{60}$); T_5: Phosphorus solubilizing bacteria (PSB); T_6:Vesicular arbuscular mycorrhiza (VAM); T_7: Urea @ 120 kg N ha^{-1} + PSB (N_{120}PSB); T_8: Urea @ 120 kg N ha^{-1} + VAM (N_{120}VAM); T_9: Urea @ 120 kg N ha^{-1} + SSP@ 30 kg P_2O_5 ha^{-1} + PSB ($N_{120}SSP_{30}$PSB); T_{10}: Urea @ 120 kg N ha^{-1} + SSP@ 30 kg P_2O_5 ha^{-1} + VAM ($N_{120}SSP_{30}$VAM); T_{11}: Urea @ 120 kg N ha^{-1} + RP @ 30 kg P_2O_5 ha^{-1} + PSB ($N_{120}RP_{30}$PSB); T_{12}: Urea @ 120 kg N ha^{-1} + RP @ 30 kg P_2O_5 ha^{-1} + VAM ($N_{120}RP_{30}$VAM). The variety used in wheat was HD 2285. The results of the soil analysis revealed that the soil was sandy loam in texture, low in organic carbon, available nitrogen and available phosphorus content and medium in potassium. The soil pH value was 7.6. The cation exchange capacity of the soil was low. Total leaf area of the fresh green functional leaves of wheat was measured at 90 DAS with the help of leaf area meter. The crop growth rate (CGR) can be calculated based on the formula:

$CGR = W_2 – W_1/ t_2 – t_1$

Where, W_1 and W_2 are plant dry weights at time t_1 and t_2 respectively. It was expressed in terms of g m^{-2} day^{-1}. The values of leaf area meter were used for determination of the leaf area index (LAI) based on the formula:

LAI = Total leaf area of the crop/ Total land area under the crop

Leaf area ratio (LAR) expresses the ratio between the area of leaf lamina or photosynthesizing tissue and the total respiring plant tissues or total plant biomasses. It reflects the leafiness of a plant. It is calculated by using the following formula:

$$LAR = LA/ W$$

Where, LA and W are leaf area and dry weight respectively. It is expressed as cm^2 of leaf area per g dry matter. Estimation of chlorophyll was done at late jointing stage by using Dimethyl sulfoxide (DMSO) method of extraction (Hiscox and Israelstam, 1979).

3. Results and Discussion

The data pertaining to the growth and chlorophyll content of wheat is presented in Table 1. The treatment $N_{120}SSP_{30}$VAM recorded highest leaf area of 224.57 cm^2 $plant^{-1}$ at 90 DAS in 2002-03 while in 2003-04 the treatment $N_{120}RP_{30}$PSB gave the highest leaf area of 230.57 cm^2 $plant^{-1}$ which was significantly different over that of $N_{120}SSP_{30}$VAM.

The highest dry matter of 4.49 g $plant^{-1}$ was associated with the treatment $N_{120}SSP_{30}$VAM in 2002-3. However, the value was statistically at par with that of $N_{120}RP_{30}$PSB. The same trend was followed in the second year. A positive correlation between application of P and dry matter production in wheat has been widely cited in the literature (Rai et al., 1982 and Singh et al., 1987).

In wheat, the treatment SSP_{60} recorded highest CGR in both the years. The CGR value of 12.20 g m^{-2} day^{-1} was observed in $N_{120}SSP_{30}$PSB in 2002-03. While in 2003-04 the higher CGR values were reported against $N_{120}SSP_{30}$VAM, $N_{120}RP_{30}$PSB and both these treatments were statistically at par. $N_{120}SSP_{30}$VAM and $N_{120}RP_{30}$PSB gave the statistically at par values of LAI in wheat at 90 DAS in 2002-3. However, in 2003-4, highest LAI of 4.61 was obtained in $N_{120}RP_{30}$PSB. At 90 DAS, treatment $N_{120}RP_{30}$PSB gave the highest LAR of 50.23 cm^2 g^{-1} in 2002-03 and 50.79 cm^2 g^{-1} in 2003-04. The highest chlorophyll content of 2.86 mg g^{-1} fresh weight was observed in $N_{120}SSP_{30}$VAM which was statistically at par with that of $N_{120}RP_{30}$VAM. During 2003-04, the treatment $N_{120}RP_{30}$VAM gave the highest chlorophyll content of 2.95 mg g^{-1} fresh weight which was statistically at par with values observed in $N_{120}SSP_{30}$VAM and $N_{120}RP_{30}$PSB. Panwar (1991) also observed that wheat inoculated with *Glomus fasciculatum* increased chlorophyll concentration and photosynthetic rate of wheat. Reduction in chlorophyll content in 2003-04 was observed only in treatment VAM, N_{120}VAM and the treatments $N_{120}RP_{30}$PSB, $N_{120}RP_{30}$-VAM recorded substantial increase in 2003-04 over that of the preceding year. This study indicates that due to inadequate and imbalanced nutrition, the chlorophyll content of leaves are reduced substantially which ultimately resulted in reduced leaf

Table 1: Effect of phosphorus on growth attributes at late jointing stage of wheat

Treatment	Leaf area (cm^2 $plant^{-1}$)		Dry matter (g $plant^{-1}$)		Crop growth rate (g m^{-2} day^{-1})		Leaf area index		Leaf area ratio (cm^2 g^{-1})		Chlorophyll (mg g^{-1} fresh wt.)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
SSP_{60}	163.07^{j}	164.60^{j}	3.88^{h}	3.93^{h}	13.00^{a}	13.20^{a}	3.26^{i}	3.29^{j}	42.07^{h}	41.89^{h}	1.70^{ef}	1.71^{ef}
RP_{60}	164.50^{j}	166.20^{j}	3.89^{h}	3.95^{gh}	12.80^{abc}	12.80^{b}	3.29^{hi}	3.32^{j}	42.25^{h}	42.11^{h}	1.60^{f}	1.68^{ef}
$N1_{20}$	177.40^{g}	178.67^{g}	4.10^{ef}	4.03^{f}	12.80^{abc}	12.20^{ef}	3.55^{f}	3.57^{g}	43.27^{g}	44.30^{e}	1.89^{de}	1.93^{de}
$N120P_{60}$	210.23^{c}	209.47^{e}	4.34^{b}	4.30^{d}	12.40^{bcd}	12.40^{cde}	4.20^{b}	4.19^{e}	48.45^{c}	48.72^{c}	2.64^{bc}	2.66^{bc}
PSB	167.03^{i}	172.83^{h}	3.99^{g}	4.00^{fg}	12.60^{bcd}	12.20^{f}	3.34^{h}	3.46^{h}	41.91^{h}	43.24^{f}	1.62^{f}	1.65^{f}
VAM	171.97^{h}	169.73^{i}	4.08^{f}	3.98^{gh}	12.80^{ab}	12.40^{def}	3.44^{g}	3.39^{i}	42.15^{h}	42.68^{g}	1.65^{f}	1.63^{f}
$N_{120}PSB$	187.83^{f}	195.97^{f}	4.10^{ef}	4.20^{e}	12.40^{cd}	12.80^{bc}	3.76^{e}	3.92^{f}	45.81^{f}	46.66^{d}	1.96^{d}	2.01^{d}
$N_{120}VAM$	193.50^{e}	194.37^{f}	4.17^{de}	4.17^{e}	12.40^{bcd}	12.60^{bc}	3.87^{d}	3.89^{f}	46.37^{e}	46.61^{d}	2.05^{d}	1.98^{d}
$N_{120}SSP_{30}PSB$	210.50^{c}	217.67^{d}	4.28^{bc}	4.38^{c}	12.20^{d}	12.60^{bcd}	4.21^{b}	4.35^{d}	49.18^{b}	49.66^{b}	2.52^{bc}	2.68^{c}
$N_{120}SSP_{30}VAM$	224.57^{a}	224.53^{b}	4.49^{a}	4.50^{ab}	12.60^{bcd}	12.60^{cde}	4.49^{a}	4.49^{b}	49.99^{a}	49.93^{b}	2.86^{a}	2.88^{ab}
$N_{120}RP_{30}PSB$	222.17^{b}	230.57^{a}	4.42^{a}	4.54^{a}	12.40^{bcd}	12.60^{bcd}	4.44^{a}	4.61^{a}	50.23^{a}	50.79^{a}	2.43^{c}	2.92^{ab}
$N_{120}RP_{30}VAM$	198.50^{d}	221.53^{c}	4.21^{cd}	4.45^{b}	12.20^{d}	12.80^{bc}	3.97	4.43^{c}	47.11^{d}	49.75^{b}	2.71^{ab}	2.95^{a}
SEm±	0.705	0.722	0.016	0.018	0.200	0.200	0.023	0.025	0.165	0.106	0.071	0.088
CD (p=0.05)	2.060	2.116	0.048	0.054	0.400	0.400	0.068	0.075	0.485	0.312	0.207	0.257

Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by Duncan's Multiple Range Test (DMRT)

area, leaf area index and dry matter. The results also suggest that in the second year of experimentation, the rock phosphate containing treatments in combination with either PSB or VAM performed better than the previous year which may be attributed to better nutrient availability from rock phosphate in presence of the bio-fertilizers.

The leaves are the main photosynthesizing organ of a plant and one of the main contributors of final grain yield. The better availability of nutrients in $N_{120}SSP_{30}VAM$, $N_{120}RP_{30}PSB$ resulted in better performance of these treatments as compared to other treatments. The combination of SSP with VAM and the same of RP with PSB in presence of N_{120} proved superior over the other combinations. The compatibility of SSP and VAM can be attributed to the fact that the vesicular arbuscular mycorrhiza might be instrumental in mobilizing the soluble P in form of SSP and might have increased the surface area of root thus enabling it to tap nutrients from otherwise inaccessible areas. Beside this VAM fungi also secrete enzymes and hormones which might have exerted beneficial effect on plant growth. The VAM fungi may also have positive effect on uptake of other nutrients like N, K and Zn. Due to the presence of only half of the recommended dose of phosphorus, there was possibly no inhibition of the performance of VAM fungi. All these facts resulted in greater compatibility of SSP and VAM. Rathore and Singh, 1995 also reported that phosphorus application and VAM inoculation increased dry matter accumulation and uptake of N, P and K by maize shoots at 30 and 45 days of growth. Inoculation with VAM fungi (*Glomus sp.*) increased shoot dry weight; N and P uptake of wheat by 82.8 % (Mikhael et al., 1997).

Similar beneficial effect of VAM was also reported by Dadhich and Somani (2007) on yield, micro nutrient uptake and post harvest availability of micronutrients in Soybean- wheat cropping sequence.

However, the treatments $N_{120}SSP_{30}PSB$ failed to give comparable performance as that of $N_{120}SSP_{30}VAM$. The phosphorus solubilizing bacteria generally release very weak organic acids in the rhizosphere. Due to lowering of soil pH in the immediate vicinity of roots, the availability of SSP was possibly not affected favourably. Since PSB has no mechanism to improve the availability of water soluble form it might have obtained no added advantage. On the other hand, due to the presence of already available form of P, there might have been some inhibition of performance of PSB and it might have failed to increase the P availability by solubilizing more of unavailable P in soil. The combination of $N_{120}RP_{30}PSB$ gave much better performance. This may be attributed to the fact that rock phosphate used had very little percentage of water soluble P and large amount of water insoluble P due to which the performance of PSB was not inhibited. On the other hand, PSB on account of its capacity to secrete acid in order to solubilise insoluble form of P might have succeeded in improving the availability of applied rock phosphate as well as organic form of indigenous unavailable soil P. So, this combination of $N_{120}RP_{30}PSB$ was effective in improving the P availability from applied P sources as well as from indigenous P sources. The result is in conformity with the report of Gaur, 1990 that citrate soluble form of phosphate can replace the water soluble form of phosphatic fertilizers, provided these are applied with phosphate solubilizing microorganisms which increase the efficiency of added water soluble and citrate soluble phosphatic fertilizers. But the combination $N_{120}RP_{30}VAM$ gave very poor performance in case of growth. The most possible explanation for such findings may be the fact that VAM fungi play important role in mobilizing available water soluble form of P by greater physical exploration of soil, faster movement of phosphorus into by mycorrhizal hyphae and through modification of root surface area for effective absorption. But in $N_{120}RP_{30}VAM$, VAM fungi might have failed to improve the availability of otherwise unavailable form of P from rock phosphate. So, this treatment failed to increase availability of P from fertilizer source and in absence of available P, the VAM fungi failed to give desirable performance.

When the chemical P sources fertilizer like SSP, RP and the phosphatic biofertilizer were applied singly, the growth was very low. This may be attributed to the absence of nitrogenous fertilizer. The element nitrogen play important role in affecting growth and development of plants and in absence of N the above mentioned treatments gave very poor growth performance. In case of wheat crop, the percent increase in dry matter yield at 90 DAS due to addition of SSP along with $N_{120}VAM$ was 7.67 % in 2002-03 and 7.90 % in 2003-04 over that of $N_{120}VAM$. Similarly, the addition of RP along with $N_{120}PSB$ resulted in 7.80 % and 8.10 % increase in 2002-03 and 2003-04 respectively over that of $N_{120}PSB$. Similar findings were also reported by Mukherjee and Rai (2000), Mahanta and Rai (2008).

The data recorded in Table 2 reveals the effect of different chemical fertilizers and biofertilizers on yield and harvest index of wheat. During both the years, the treatments $N_{120}SSP_{30}VAM$ and $N_{120}RP_{30}PSB$ were statistically at par. However, during 2002-03, the highest grain yield of 59.56 q ha^{-1} was recorded in treatment $N_{120}SSP_{30}VAM$ while in 2003-04, the highest value of 60.32 q ha^{-1} was recorded in $N_{120}RP_{30}PSB$. During 2003-04, the treatment $N_{120}RP_{30}VAM$ was statistically at par with $N_{120}SSP_{30}VAM$. The lowest grain yield of 36.92 q ha^{-1} and 33.59 q ha^{-1} was recorded in 2002-03 and 2003-04 respectively in treatment RP_{60}. The grain yield registered a decline over previous year in treatment SSP_{60}, RP60, N_{120}, PSB, VAM, $N_{120}VAM$, while it improved in rest of the treatments.

During 2002-03 the stover yield of $N_{120}P_{60}$, $N_{120}SSP_{30}VAM$, $N_{120}RP_{30}PSB$ were statistically at par while the highest value

Table 2: Effect of treatments on yield and harvest index of Wheat

Treatment	Grain yield (q ha^{-1})			Stover yield (q ha^{-1})			Harvest index		
	2002-03	2003-04	Pooled	2003-04	2002-03	Pooled	2002-03	2003-04	Pooled
SSP_{60}	40.44^{f}	37.99^{f}	39.22	63.88^{f}	61.66^{de}	62.77	0.39^{bc}	0.38^{b}	0.385
RP_{60}	36.92^{g}	33.59^{h}	35.26	58.21^{h}	55.21^{g}	56.71	0.39^{bc}	0.38^{b}	0.405
$N1_{20}$	44.61^{e}	43.42^{e}	44.02	67.55^{e}	64.30^{d}	65.93	0.40^{abc}	0.41^{a}	0.415
$N120P_{60}$	55.49^{bc}	55.58^{c}	55.54	78.69^{ab}	79.44^{b}	79.07	0.41^{ab}	0.42^{a}	0.380
PSB	38.59^{fg}	36.05^{fg}	37.32	60.65^{gh}	60.50^{ef}	60.58	0.39^{c}	0.37^{b}	0.380
VAM	39.74^{f}	35.68^{gh}	37.71	62.72^{fg}	58.17^{f}	60.45	0.39^{c}	0.38^{b}	0.420
$N_{120}PSB$	48.99^{d}	50.54^{d}	49.77	69.68d^{e}	71.62^{c}	70.65	0.42^{ab}	0.42^{a}	0.415
$N_{120}VAM$	49.78^{d}	49.37^{d}	49.58	71.29^{d}	69.81^{c}	70.55	0.41^{abc}	0.42^{a}	0.420
$N_{120}SSP_{30}PSB$	55.08^{c}	57.50^{bc}	56.29	76.50^{bc}	81.56^{ab}	79.03	0.42^{a}	0.42^{a}	0.430
$N_{120}SSP_{30}VAM$	59.56^{a}	60.22^{a}	59.89	80.78^{a}	82.31^{ab}	81.55	0.43^{a}	0.43^{a}	0.420
$N_{120}RP_{30}PSB$	57.43^{ab}	60.32^{a}	58.88	79.46^{a}	84.55^{a}	82.01	0.42^{a}	0.42^{a}	0.420
$N_{120}RP_{30}VAM$	54.94^{c}	59.24^{ab}	57.09	75.32^{c}	82.85^{a}	79.09	0.42^{a}	0.42^{a}	0.165
SEm±	0.763	0.728		0.947	1.000		0.008	0.006	
CD (p=0.05)	2.238	2.135		2.779	2.935		0.024	0.017	

Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by Duncan's Multiple Range Test (DMRT) of 80.78 q ha^{-1} was recorded in treatment $N_{120}SSP_{30}VAM$. During 2003-04, the highest treatment was associated with $N_{120}RP_{30}PSB$ (84.55 q ha^{-1}) and it was statistically at par with that of $N_{120}SSP_{30}PSB$, $N_{120}SSP_{30}VAM$, $N_{120}RP_{30}VAM$. The highest pooled value of 81.55 q ha^{-1} was associated with treatment $N_{120}SSP_{30}VAM$. During both the years the treatment RP_{60} recorded the lowest stover yield. In treatment SSP_{60}, RP_{60}, N_{120}, PSB, VAM, $N_{120}VAM$, the stover yield decreased in 2003-04. In 2002-03, the harvest index value varied from the lowest value of 0.39 observed in treatments SSP_{60}, RP_{60}, PSB, and VAM to the highest value of 0.43 observed in treatment $N_{120}SSP_{30}VAM$. During 2003-04, the lowest value of 0.37 was recorded in PSB, while the highest value of 0.43 was recorded in $N_{120}SSP_{30}VAM$. The treatments SSP_{60}, RP_{60}, PSB, VAM were statistically at par and the rest treatments were also statistically at par among themselves. The superiority of treatments $N_{120}SSP_{30}VAM$ in 2002-03 and that of $N_{120}RP_{30}PSB$ in 2003-04 in terms of number of spikes m^{-2} might have been responsible for higher grain and stover yield in treatments $N_{120}SSP_{30}VAM$ and $N_{120}RP_{30}PSB$ during both the years. It was also observed SSP_{60}, RP_{60}, N_{120}, PSB, VAM and $N_{120}VAM$ experienced yield reduction during 2003-04. This may be attributed to the severe depletion of nitrogen in treatments SSP_{60}, RP_{60}, PSB, and VAM where no N-fertilizer was added. However, yield reduction in N_{120} suggested that the total absence of P fertilizer even in presence of full dose of nitrogen can not be a sustainable practice. Comparing $N_{120}PSB$ and $N_{120}VAM$ it was observed that slight yield reduction occurred in $N_{120}VAM$ in 2002-03 while slight yield increase was observed in $N_{120}PSB$. This may be justified from the fact that in absence of addition of any phosphatic fertilizer sources, the P mobilizers i.e. VAM might have mobilized all the available P sources and probably very little available P sources would have left over.

But on the other hand, the PSB gradually release organic acids to solubilize insoluble inorganic and organic P sources and thus bring more of the unavailable P sources into the available P pool. Thus, depletion of available P sources might have occurred to lesser extent treatments involving PSB. The greater P availability might have triggered better root growth, nutrient uptake and finally better yield components and higher grain yield. Gaur (1985) also reported the positive effect of *Pseudomonas striata* on P uptake and grain yield of wheat. However, during 2002, the VAM inoculated treatments resulted in better yield components and yield than PSB inoculated treatments. Tarafdar and Marschner (1995) observed that soil inoculation with the VAM fungus *Glomus mosseae* increased plant height, shoot and root dry weight and root length, phosphatase activity in the rhizosphere and shoot concentrations of P and to a lesser extent of K and Mg.

4. Conclusion

The treatments $N_{120}SSP_{30}VAM$, $N_{120}RP_{30}PSB$ were able to out perform $N_{120}P_{60}$. The chlorophyll content was highest in treatments $N_{120}SSP_{30}VAM$ in 2002 and in $N_{120}RP_{30}VAM$ in 2003. Higher yields were observed in $N_{120}SSP_{30}VAM$ in 2002-03 and in $N_{120}RP_{30}PSB$ in 2003-04.

Thus it can be concluded that the treatments $N_{120}SSP_{30}VAM$, $N_{120}RP_{30}PSB$ favourably affected the growth parameters and yield of wheat. By using VAM along with SSP and PSB along with rock phosphate, the use of chemical fertilizers can be minimized without compromising the yield and at the same time, vast reserves of low P containing rock phosphates of our country can be effectively and efficiently utilised.

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