Effect of different levels of Phosphorus and Biofertilizers on Yield and Economics of Wheat (*Triticum aestivum* L.)

ABSTRACT

An experiment was conducted in the winter season of 2023 at Crop Research Farm, Dev Bhoomi Uttarakhand University, Dehradun. The study, conducted in a Randomised Block Design (4x3 factorial) with three replications, aimed to analyze the impact of different levels of Phosphorus PSB and VAM on the development and production of wheat. Among all treatments, Treatment P3 (60 kg ha^{-1} Phosphorus) showed the best results in terms of growth factors like plant height, dry weight, number of tillers, crop growth rate, and relative growth rate. Additionally, yield attributes and overall yield were significantly higher in Treatment P3 compared to the other treatments. O3 (PSB + VAM) demonstrated the highest growth attributes, yield attributes, and yield for wheat among biofertilizers.

Keywords Wheat, Phosphorus, Phosphate Solubilizing Bacteria, Vesicular-Arbuscular Mycorrhizae, Yield, Economics

INTRODUCTION

Wheat is the second most important food crop in India, primarily consumed in the northern and north-western regions. It is a good nutritional supplement, containing 9-10% protein and 60-80% carbohydrates, making it a balanced food source for millions. India has the largest area of wheat cultivation at 29.14 million hectares but ranks second in production with 102.19 million tonnes, following China. The average productivity is 3154 kg/ha GOI (2019). Wheat is mainly cultivated in Uttar Pradesh, Punjab, Rajasthan, Haryana, Bihar, Madhya Pradesh, Gujarat, and Maharashtra, covering about 14% of the country's total cropped area. India contributes approximately 12% of the world's wheat production. Phosphorus (P) is vital for plant growth and is a major growth-limiting nutrient despite its abundance in soils in both inorganic and organic forms Gyaneshwar *et al*. (1999). Plants absorb phosphorus in the form of orthophosphate Hinsinger (2001). Phosphorus is a structural component of many co-enzymes, phosphoproteins, and phospholipids Ozanne (1980) and is part of the DNA of all living organisms. It is involved in energy transfer and storage, crucial for growth and reproduction Griffith (1999). Phosphorus also plays a key role in several physiological processes in plants, including photosynthesis, carbon metabolism, and membrane formation Wu *et al.* (2005).

Microorganisms are essential in the natural phosphorus cycle. They produce acids that reduce soil pH and dissolve bound phosphates. Some hydroxyl acids may chelate with calcium and iron, effectively solubilizing and utilizing phosphates. Inoculating soil with suitable PSB isolates can reduce the need for phosphorus fertilizers. The high cost of phosphorus fertilizers and their fixation in soil necessitate sustainable phosphorus nutrition for crops in developing countries like India. Vesicular Arbuscular Mycorrhiza (VAM) is a complex structure in plant roots formed by the mutual interactions of soil fungi and root tissues. VAM primarily mobilizes soil phosphorus, enhancing phosphorus uptake by plants Toljander (2006). The increased phosphorus absorption in VAM-infected plants is attributed to enzyme phosphatase activities George *et al*. (1992).

The rice-wheat cropping system (RWCS) is predominant in the Indo-Gangetic Plains, covering a significant portion of the arable land in South Asia. This system is crucial for regional food security but faces challenges like soil fertility depletion, nutrient imbalance, and declining crop productivity. Phosphorus is often a limiting nutrient in RWCS due to its low soil availability. Traditional phosphorus fertilizers are used to address this deficiency, but their effectiveness is limited by soil chemical properties that reduce phosphorus availability to plants. Phosphate solubilizing bacteria (PSB) and vesicular-arbuscular mycorrhizae (VAM) are beneficial microorganisms that enhance phosphorus availability and uptake by solubilizing insoluble phosphorus compounds and increasing root surface area. This research aims to evaluate the combined effects of different phosphorus levels, PSB, and VAM on wheat yield and economic return. Understanding these interactions is essential for developing sustainable nutrient management practices that optimize crop productivity and economic viability.

MATERIAL AND METHODS

Experimental site: The trial took place at the Crop Research Farm of Dev Bhoomi Uttarakhand University in Dehradun, Uttarakhand, in the *Rabi* Season of 2023. Temperatures range from 35 to 39 degrees Celsius in summer and drop to 0.5 degrees Celsius in winter. On average, the majority of the annual 1040.4 mm of rain falls between November and the end of April.

Soil: The soil was moist, well drained with uniform plane topography. The soil of the experimental field was alluvial in origin, sandy loam in texture and slightly alkaline in reaction having pH 7.6 (1:2.5 soil: water suspension method given by Jackson (1973), electrical conductivity 0.45 and 0.44 dSm-1 (1:2.5 soil: water suspension method given by Jackson, 1973), Organic carbon percentage in soil is 0.24% (Walkley & Black's rapid titration method given by Walkley& Black (1934) with available nitrogen 237 kg/ ha (Alkaline permanganate method given by Subbiah & Asija (1956), available phosphorus as sodium bicarbonate-extractable P was 19.60 kg/ ha (Olsen's calorimetrically method, Olsen *et al.* (1954) .

Experimental Design: The research used a random block format with 12 treatment combinations repeated three times. Treatments were randomly assigned to 36 plots in every replication. The treatments specify a combination of layout specifications and more.

Details of Treatment

Factor A (Phosphorus levels)

P1 – Phosphorus 40 kg/ha

P2 – Phosphorus 50 kg/ha

P3 – Phosphorus 60 kg/ha

P4 – Phosphorus 70 kg/ha

Factor B (Biofertilizers levels)

O1– PSB

O2 – VAM

O3 – PSB+ VAM

Table 1. Detail of the treatment combinations

S. No	Treatment No.	Treatment combination	Treatment Description
1.	T_1	P_1O_1	PSB+40kg P_2 O_5 /ha
2.	T_2	P_1O_2	VAM+40kg P_2 O_5 /ha
3.	T_3	P_1O_3	PSB +VAM+40kg P_2 O_5 /ha
4.	T_4	P_2O_1	PSB+50kg P_2 O_5 /ha
5.	T_5	P_2O_2	VAM+50kg P_2 O_5 /ha
6.	T_6	P_2O_3	PSB +VAM+50kg P_2 O_5 /ha
7.	T_7	P_3O_1	PSB+60kg P_2 O_5 /ha
8.	T_8	P_3O_2	VAM+60kg P_2 O_5 /ha
9.	T_9	P_3O3	PSB +VAM+60kg P_2 O_5 /ha
10.	T_{10}	P_4O_1	PSB+70kg P_2 O_5 /ha
11.	T_{11}	P_4O_2	VAM+70kg P_2 O_5 /ha
12.	T_{12}	P_4O_3	PSB +VAM+70kg P_2 O_5 /ha

Harvesting and threshing: The crop was harvested once it reached the appropriate level of maturity as determined through visual evaluations on (20 April 2024). In order to avoid mistakes, two border rows were eliminated on both sides of the field, along with reducing half a meter from the length of each plot. The harvest from the enclosed area was gathered for the purpose of determining yield data. Produce was gathered and measured to determine biomass yield. Each person's small plot of land had its produce threshed using a manual thresher.

Data Collection

Growth parameter

Plant height (cm): For each plot, five plants were selected at random and marked for measuring their height at different time intervals. Height was measured at 30, 60, and 90 DAS and also at harvest by using a meter scale from the ground to the top leaf pre-heading, and from the ear head base post-heading.

Leaf area index (LAI): The leaf area index was determined by measuring the leaf area 30, 60, and 90 days post-sowing. Plants were chosen with a row length of 0.25 m, and their green leaves were separated to measure surface area with an automatic leaf area meter.

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Crop growth rate (g m^{-2} day^{-1}): It refers to the quantity of plant matter obtained by a designated space of a crop during a set time frame, recorded in grams per square meter per day. The crop growth rate was determined by analyzing the dry matter production data gathered for each treatment at 30, 60, and 90 DAS. The formula provided was used for the calculation.

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1}$$

Relative growth rate (RGR): Fisher and Yates (1947) defined it as the growth rate of dry weight per unit dry matter during a specific time period and it can be calculated using the equation below:

$$\log_e W_2 - \log_e W_1$$

Relative growth rate (RGR) = ————————

$t_2 - t_1$

Yield parameter

Ear par plant: After threshing the Ear par plant from each plot was separately weighed and recorded after converting into quintals per hectare.

Seed per plant: After threshing the seed par plant from each plot was separately weighed and recorded after converting into quintals per hectare.

Grain yield: After threshing the grain yield from each plot was separately weighed and recorded after converting into quintals per hectare.

Straw yield: After subtracting the grain yield per plot from the total biological yield. After converting the yields into quintals per hectare, yields were recorded.

Harvest index (%): The recovery of grains in total dry matter was considered as harvest index, expressed in percentage. It has been calculated by following formula:

Harvest Index (%) = [Seed Yield (q ha-1) / Biological Yield (q ha-1)] x 100

Economics: The economics of different treatments was worked out on the basis of average yield (seed and stover) of 2023-24.

Cost of cultivation (INR ha-1): The cost of cultivation was worked out on the basis of input rates at the farm. Treatments cost was calculated separately. The common cost of cultivation (INR ha-1) was worked out by considering all the expenses incurred in the cultivation and added variable cost due to treatments (including interest of working capital) in order to get total cost of cultivation.

Gross return (INR ha-1): The overall income was determined by multiplying the crop and straw production with the prevailing market rate in various conditions. The total income (Rs /ha) was calculated by adding up the earnings from both the grain and straw harvest.

Gross return (INR ha^{-1})= Total income from the grain and straw harvest

Net return (INR ha-1): Net profit is the outcome received by subtracting the cost of cultivation from gross income (INR ha^{-1}). The net return was worked out by using following formula

Net return (INR ha^{-1}) = Gross return (INR ha^{-1}) - Cost of cultivation (INR ha^{-1})

Benefit cost ratio (Rupee ha^{-1} invested):

$$B:C = \frac{\text{Net return (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})}$$

Statistical analysis

The data recorded for different characteristics were subjected to statistical analysis using Fisher method of analysis of variance (ANOVA). Critical difference (CD) values were calculated when the 'F' test was found significant at the 5% level.

RESULTS AND DISCUSSION

Growth attributes

Plant height (cm): Plant height was not directly affected grain yield, indicating that nutrient levels impacted plant metabolism. Treatment T9 reached the tallest height at harvest (68.51 cm), similar to T6 and T8 (Table 2, Fig 1). This increase in the height may be influenced by genetic factors and the application of phosphorus, PSB, and VAM, which enhanced auxin production and phosphorus availability Amanullah *et al*. (2013); Ojaghloo *et al*. (2007). Plant height increased with phosphorus levels up to 60 kg/ha, supported by improved nutrition that boosted photosynthesis, assimilation, cell division, and vegetative growth Afzal *et al*. (2005). Biofertilizer application also contributed to taller plants. PSB + VAM likely enhanced plant metabolism and provided available phosphorus crucial for enzyme systems regulating wheat plant metabolic activities Surendra *et al*. (2000).

Plant dry weight (g): The maximum plant dry weight (18.41g) was observed in treatment T9, with treatments T6 and T8 showing statistically similar results to T9. The increase in plant dry weight can be attributed to a larger assimilatory surface area, which facilitated higher dry matter production and efficient translocation of photosynthates from source to sink Kumar *et al.* (2022). Dry matter accumulation responded positively to phosphorus doses up to 60 kg/ha, enhancing leaf area, leaf number, and tiller count, ultimately boosting plant dry weight Biofertilizer application also contributed to increased dry matter accumulation, correlating with enhanced growth and development, including more tillers per square meter Kumar (2022).

Number of tiller/plant: Observations on the number of tillers at 60 DAS revealed significant differences among treatments. Treatment T9 recorded the maximum number of tillers (5.17), with T6 and T8 showing statistically similar results to T9. Treatment T10 had the minimum number of tillers (4.26) at 60 DAS. The higher number of tillers in T9 (60 kg/ha phosphorus +

PSB + VAM) was likely due to enhanced nitrogen-fixing and phosphate-solubilizing microorganisms, which promoted wheat growth and yield while potentially reducing dependency on chemical fertilizers Amanullah *et al.* (2013). Tillers increased with phosphorus doses up to 60 kg/ha, impacting chlorophyll formation and influencing carbohydrate and protein metabolism, despite not being a chlorophyll constituent itself. Phosphorus and biofertilizer applications likely influenced vegetative growth, contributing to increased tiller production Kumar (2022).

Leaf area Index: Examination of the average data indicated significant differences in leaf area index across various growth environments. The highest leaf area index was observed in B3 (PSB + VAM) at 0.30, 1.31, 2.50, and 1.39 at 30, 60, 90, and harvest respectively. A thorough analysis of the data showed that B3 had an increase of 6.66% at 30 DAS, 8.39% at 60 DAS, 8.4% at 90 DAS, and 7.19% at harvest compared to B1 and B2. Data suggests that B1 and B2 (PSB, VAM) had the lowest leaf area index. Treatment T9 (60 kg Phosphorus / ha) had the highest leaf area index among PSB + VAM treatments.

Crop growth rate (g m^{-2} day^{-1}) and Relative growth rate (g g^{-1} day^{-1}): The highest Crop Growth Rate (CGR) (12.76) and Relative Growth Rate (RGR) (18.41) were recorded in treatment T9 from 60 DAS until harvest, while the lowest CGR (10.02) in treatment T1 and RGR (15.17) were observed in treatment T10 (Table 2, Fig 1). The increase in CGR and RGR was attributed to favourable conditions of low temperatures and reduced humidity during the reproductive stage, along with phosphorus and PSB seed inoculation that likely enhanced phosphorus uptake through microbial synergies Surendra *et al.* (2000). VAM, PSB, and phosphorus are crucial for photosynthesis, root formation, growth, yield, and crop maturity, significantly promoting CGR and RGR as well Kumar (2022). Amanullah *et al.* (2013) also reported that phosphorus application up to 60 kg/ha progressively and significantly enhanced growth and yield parameters.

Yield attributes

Wheat had a significant effect on the yield parameters with levels of Phosphorus and Biofertilizers (PSB and VAM). Significant and highest grain yield (39.87t ha^{-1}), straw yield (48.97t ha^{-1}), Test weight (42.55g) and Harvest index (44.90%) was recorded in treatment T9 (60 kg ha^{-1} P + PSB+VAM), while lowest grain yield (32.86 t ha^{-1}), straw yield(40.36t ha^{-1}), Test weight (35.06g) and Harvest index (44.33%) was recorded in treatment T10 (40 kg ha^{-1} P + PSB) (Table 3 and Fig. 2). This might be due to genetic ability of the plant attributed to higher biomass accumulation coupled with effective translocation and distribution of photosynthates from source to sink, which in turn resulted into elevated stature of yield attributes. The probable reason for recording higher grain yield under treatment T9 (60 kg ha^{-1} phosphorus + PSB+VAM) might be due to phosphorus application because phosphorus was directly related to the vegetative and reproductive phases of the crop and attributes complex phenomenon of phosphorus utilization in plant metabolism. It also helped in the efficient absorption and utilization of the other required plant nutrients which ultimately increased the grain yield Surendra *et al.* (2000).

Table 2. Effect of different treatment combination on growth parameters of wheat

	Treatments	Plant height (cm)	Plant dry Weight (g)	No. of tiller $plant^{-1}$	Leaf area index (%)	CGR (g m^{-2} day^{-1})	RGR (g g^{-1} day^{-1})
T1	PSB + Phosphorus 40 kg ha^{-1}	57.94	15.38	4.34	1.21	10.02	15.38
T2	VAM + Phosphorus 40 kg ha^{-1}	61.00	16.39	4.60	1.28	11.36	16.39
T3	PSB +VAM + Phosphorus 40 kg ha^{-1}	64.77	17.41	4.88	1.36	12.07	17.41
T4	PSB + Phosphorus 50 kg ha^{-1}	60.16	16.17	4.54	1.27	11.21	16.17
T5	VAM + Phosphorus 50 kg ha^{-1}	64.55	17.35	4.87	1.36	12.02	17.35
T6	PSB +VAM + Phosphorus 50 kg ha^{-1}	67.99	18.28	5.13	1.43	12.67	18.28
T7	PSB + Phosphorus 60 kg ha^{-1}	62.87	16.90	4.74	1.32	11.71	16.90
T8	VAM + Phosphorus 60 kg ha^{-1}	66.76	17.94	5.03	1.40	12.44	17.94
T9	PSB + VAM + Phosphorus 60 kg ha^{-1}	68.51	18.41	5.17	1.44	12.76	18.41
T10	PSB + Phosphorus 70 kg ha^{-1}	56.46	15.17	4.26	1.19	10.52	15.17
T11	VAM +Phosphorus 70 kg ha^{-1}	62.43	16.78	4.71	1.31	11.63	16.78
T12	PSB + VAM + Phosphorus 70 kg ha^{-1}	63.42	17.05	4.78	1.33	11.81	17.05
	F-test	NS	NS	NS	NS	NS	NS
	S.Ed(±)	2.55	2.55	0.19	0.05	3.60	0.69
	CD (P=0.05)	5.28	5.28	0.40	0.11	7.47	1.43

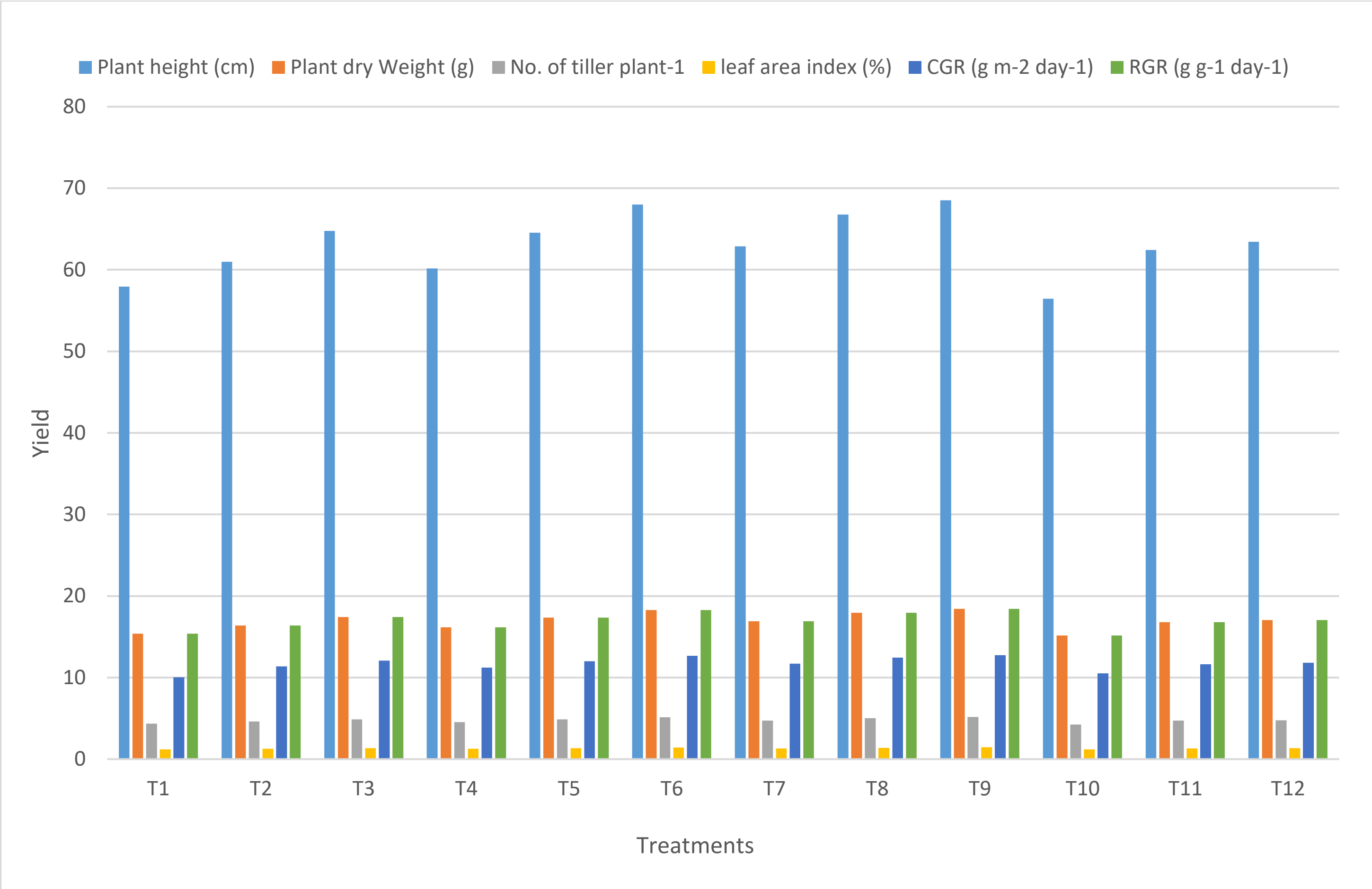

Fig 1. Effect of Different Levels of Phosphorus and Biofertilizers (PSB and VAM) on Growth Attributes viz, Plant height (cm), Plant dry weight(g), Number of leaves plant^{-1}, CGR (g m^{-2} day^{-1}) and RGR (g g^{-1} day^{-1}).

Table 3. Effect of different treatment combination on yield parameters of wheat

	Treatments	Ear par plant	Seed per plant	Grain yield (t ha^{-1})	Straw yield(t ha^{-1})	Test weight (g)	Harvest Index (%)
T1	PSB + Phosphorus 40 kg ha^{-1}	3.91	46.28	32.96	41.38	37.34	44.80
T2	VAM + Phosphorus 40 kg ha^{-1}	4.14	48.73	35.50	43.60	37.88	44.88
T3	PSB +VAM + Phosphorus 40 kg ha^{-1}	4.39	51.74	37.70	46.30	40.23	44.88
T4	PSB + Phosphorus50 kg ha^{-1}	4.08	48.06	35.02	43.01	37.37	44.90
T5	VAM + Phosphorus 50 kg ha^{-1}	4.38	51.56	37.57	46.14	40.09	44.90
T6	PSB +VAM + Phosphorus 50 kg ha^{-1}	4.61	54.32	39.57	48.60	42.23	44.88
T7	PSB + Phosphorus 60 kg ha^{-1}	4.26	50.23	36.59	44.94	39.05	44.88
T8	VAM + Phosphorus 60 kg ha^{-1}	4.53	53.33	38.86	47.73	41.47	44.88
T9	PSB + VAM + Phosphorus 60 kg ha^{-1}	4.65	54.72	39.87	48.97	42.55	44.90
T10	PSB + Phosphorus 70 kg ha^{-1}	3.83	45.10	32.86	40.36	35.06	44.33
T11	VAM +Phosphorus 70 kg ha^{-1}	4.23	49.87	36.34	44.63	38.77	44.89
T12	PSB + VAM + Phosphorus 70 kg ha^{-1}	4.30	50.66	36.91	45.34	39.39	44.88
	F-test	NS	NS	NS	NS	NS	NS
	S.Ed(±)	0.17	2.03	1.52	1.82	1.66	1.75
	CD (P=0.05)	0.36	4.22	3.15	3.77	3.43	3.62

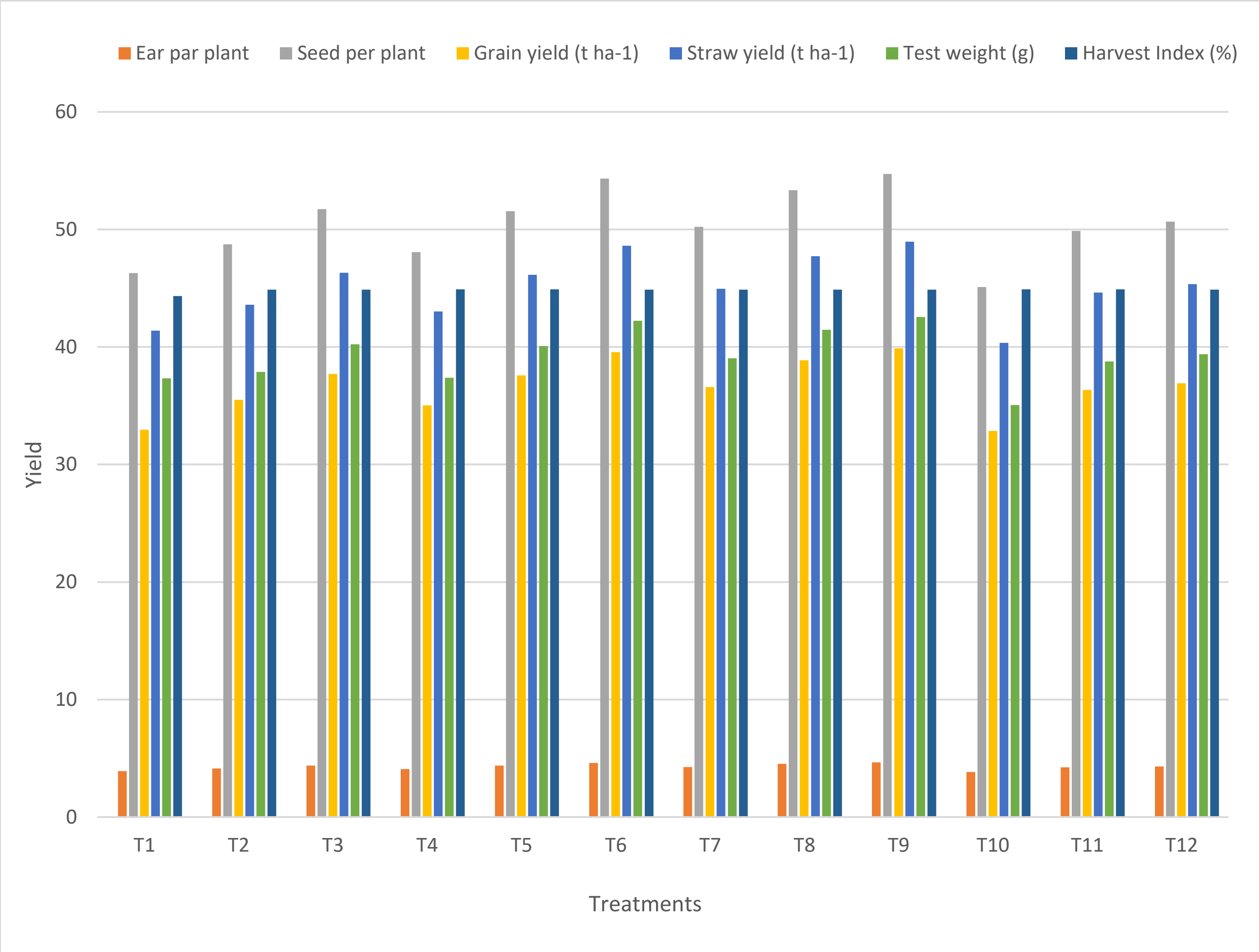

Fig. 2. Effect of different treatment combination on yield parameters of wheat

Economics

The highest gross return (56085Rs ha^{-1}), net return (36275 Rs ha^{-1}) and B:C ratio (2.90) was observed in treatment T9 (60 kg ha^{-1} P + PSB+VAM), while lowest gross return (49690 Rs ha^{-1}), net return (31774 Rs ha^{-1}) was observed in treatment T1 (Table 4 and Fig 3). The probable reason for recording higher economic sunder treatment T9 (60 kg ha^{-1} phosphorus+ PSB+VAM) might be due to use of biofertilizers plus half a dose of organic and chemical fertilizers have resulted in highest gross return and net return.

Table 4. Effect of different treatment combination on economics parameters of wheat

	Treatments	Gross return ($Rs\ ha^{-1}$)	Net return($Rs\ ha^{-1}$)	B: C ratio
T1	PSB + Phosphorus 40 kg ha^{-1}	49690	31774	2.1
T2	VAM + Phosphorus 40 kg ha^{-1}	51940	33623	2.84
T3	PSB +VAM + Phosphorus 40 kg ha^{-1}	54230	35480	2.89
T4	PSB + Phosphorus50 kg ha^{-1}	51530	33154	2.80
T5	VAM + Phosphorus 50 kg ha^{-1}	53780	35003	2.86
T6	PSB +VAM + Phosphorus 50 kg ha^{-1}	56070	36060	2.01
T7	PSB + Phosphorus 60 kg ha^{-1}	51955	33019	2.74
T8	VAM + Phosphorus 60 kg ha^{-1}	54205	34868	2.80
T9	PSB + VAM + Phosphorus 60 kg ha^{-1}	56085	36275	2.90
T10	PSB + Phosphorus 70 kg ha^{-1}	52430	32834	2.68
T11	VAM +Phosphorus 70 kg ha^{-1}	54680	34683	2.73
T12	PSB + VAM + Phosphorus 70 kg ha^{-1}	56020	36090	2.77

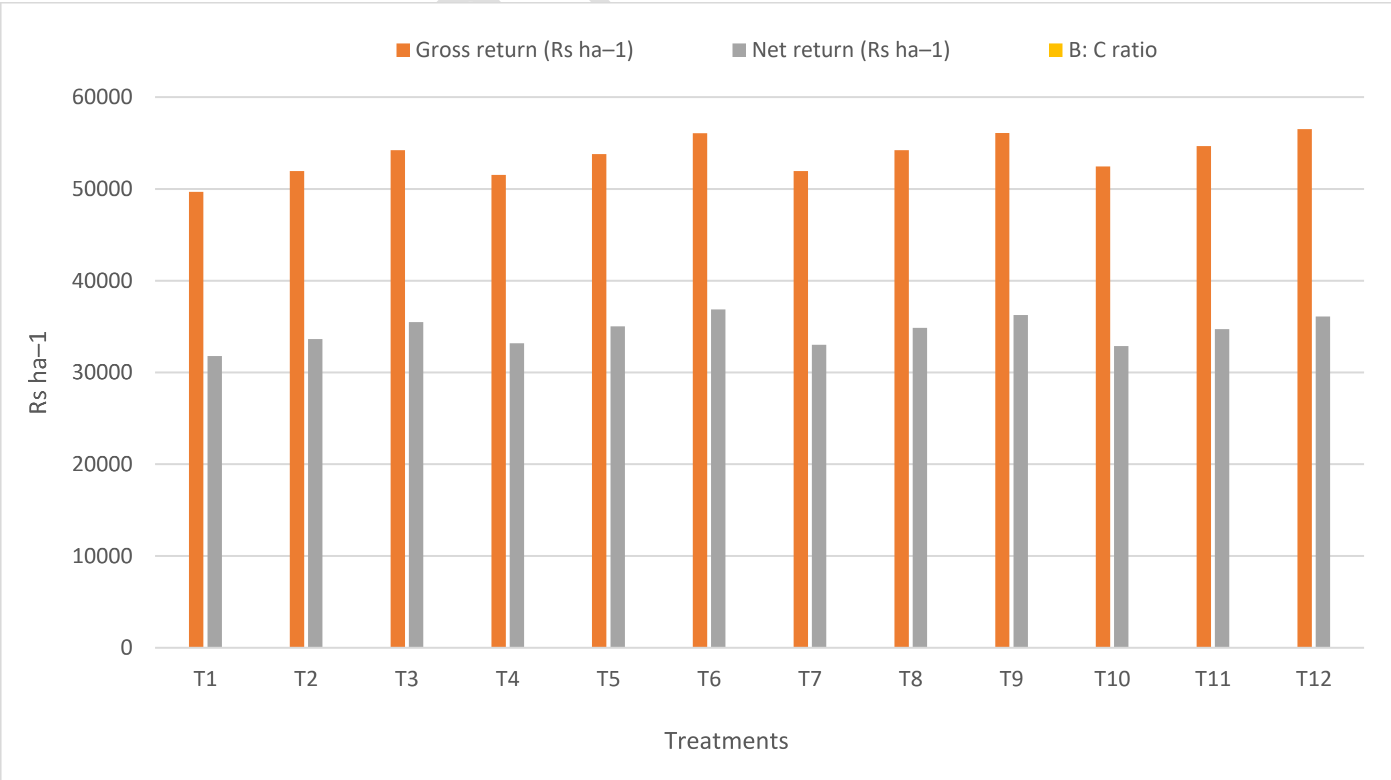

Fig. 3. Effect of different levels of phosphorus and biofertilizers (PSB and VAM) on gross return, net return and B: C ratio

CONCLUSION

The study concluded that applying 60 kg/ha phosphorus in combination with PSB and VAM significantly improved growth attributes, yield attributes, and yield of wheat. Treatment T9 (60 kg/ha phosphorus + PSB + VAM) was the most effective, resulting in the highest plant height, dry weight, number of tillers, grain yield, straw yield, and harvest index. The use of biofertilizers, particularly PSB and VAM, played a crucial role in enhancing phosphorus availability and uptake, leading to better overall growth and higher yields. This combination of phosphorus and biofertilizers can be recommended for sustainable nutrient management in wheat cultivation, optimizing crop productivity and economic return.

REFERENCE

Afzal A, Ashraf M, Saeed A, Asad, Farooq M (2005) Effect of phosphate solubilizing microorganisms on phosphorus uptake, yield and yield traits of wheat (*Triticum aestivum* L.) in rainfed area. *International Journal of Agricultural Biology* 7:207-9.

Amanullah, Khan AZ, Khan F (2013) Foliar application of nitrogen at different growth stages influences the phenology, growth and yield of wheat. *Soiland Environment* 32:135-140.

Asghar A, Ali A, Syed WH, Asif M, Khaliq T, Abid AA (2010) Growth and yield of maize (*Zea mays* L.) cultivars affected by NPK application in different proportion. *Pakistan Journal of Science* 3:213-216.

George E (1992) Contribution of mycorrhizal hyphal to nutrient and water uptake of plants. Mycorrhizas in Ecosystems 42-47.

Girma K, Raun B, Zhang H, Mosali J (2006) What about foliarp on corn and winter wheat. *Fluid Journal* 14(3):17-19.

GOI (2019) Agricultural statistics at a glance. Directorate of Economics and Statistics. Department of Agriculture and Cooperation, Ministry of Agriculture. *Current Science* 25:259-60.

Griffith B (1999) Phosphorus Efficient Fertilizer Use Manual, fourth ed. IMC Global http://www.imcagro.com/fertilize/education/ efu manual. (Accessed 5 January 2018).

Gyaneshwar P, Parekh LJ, Archana G, Podle PS, Collins MD, Hutson RA *et al* (1999) Involvement of a phosphate starvation inducible glucose dehydrogenase in soil phosphate solubilization by *Enterobacter asburiae.* FEMS *Microbial Lett* 171:223-229.

Hinsinger P (2001) Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical change: a review. *Plant Soil* 237:173-195.

Jackson ML (1973) Soil chemical analysis. New Delhi: Prentice Hall of India Pvt. Ltd.

Kumar A, Dimree S, Sachan R, Shekhar C, Gangwar K, Kumar M (2022) Effect of FYM and zinc on growth, yield attributes and productivity parameters of wheat (*Triticum aestivum* L.). *Asian J Microbiol Biotechnol Environ Sci* 24(4):20-3 ISSN-0972-3005.

Kumar P, Dubey SD, Sachan R, Rawat CL, Kumar V (2022) Effect of organic manure, inorganic fertilizers and biofertilizers on nutrient content of maize (Zea mays L.) and their residual effect on succeeding wheat (*Triticum aestivum* L.) crop. I*nt J Plant Soil Sci* 34(20):817-27.

Ojaghloo F, Farahvash F, Hassanzadeh A. and Pouryusef, M (2007) Effect of inoculation with barvar phosphate bio- fertilizers on yield of safflower (*Carthamus tinctorius* L.)*Journal of Agricultural Sciences,* Islamic Azad University, Tabriz Branch 3:25-30.

Olsen SR, Cole CV, Watanable FS, Dean LA (1954) Estimation of available phosphorous in soil by extraction with sodium bicarbonate. *USDA Cric*. 930:19-23.

Ozanne PG (1980). Phosphate nutrition of plants general treatise. In: The Role of Phosphorus in Agriculture. *American Society of Agronomy and Science Society of America*, Madison, WI, USA 559-589p.

Parvez K, Memon MY, Imtiaz M, Aslam M (2009) Response of wheat to foliar and soil application of urea at different growth stages. *Pakistan Journal of Botany* 41:1197-1204.

Singh R, Khan MA (2003) Response of clusterbean (*Cyamopsis tetragonoloba* L.) varieties to fertility levels and cropping systems under arid condition. *Advances in arid legume research* 225-228.

Subbiah BV, Asija CL (1956) A rapid procedure for the estimation of available N in Soil. *Curr Sci* 25:259-60.

Surendra ST, Sharanappa (2000) Integrated management of nitrogen and phosphorus in maize (*Zea mays*) and their residual effect on cowpea (*Vigna unguiculata*). *Indian Journal of Agricultural Sciences* 70(2):119-121

Toljander JF (2006) Interaction between soil bacteria and arbuscular mycorrhizal fungi. Swedish University of Agricultural Sciences, Uppsala. Final Ph.D. Thesis.

Walkley A, And Black IA (1934) Old piper, S.S. soil and plant analysis. Soil Sci 37(1): 29-38. DOI: 10.1097/00010694-193401000-00003

Wu SC, Cao ZH, Li ZG, Cheung KC, Wong MH (2005) Effect of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on wheat growth: a greenhouse trial. *Geoderma* 125:155-166.