Impact of Bioinoculants on Grain yield and economics of wheat(*Triticum aestivum* L.)during Rabi season

Abstract

Field experiments were conducted to Studies effect integrated nutrient management on yield and economics of wheat during Rabi season of 2020-21 and 2021-22 at student's instructional farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. The experiment consists of 11 treatments combinations in randomized block design with three replications consisted of three replications consisted of different combination of inorganic fertilizer, organic manure and biofertilizers .Wheat variety HD-2967 was grown with the recommended agronomic practices.On the basis of results emanated from investigation it can be concluded that among the productivity parameters viz. maximum grain yield was 48.60 and 49.93q ha^{-1}, straw yield was 63.15 and 67.53 q ha^{-1} and biological yield was 111.75 and 117.46 q ha^{-1} during the both years of experimentation are associated with the treatment T_{10} [100 % NPK + S_{40} + Zn_5 + Fe_{10} + Azotobacter + PSB + 5 ton FYM]. Maximum gross return ₹ 140190 and ₹ 141127, during the first year (2020-21) and second year (2021-22) of experimentation were recorded under treatment T_{10} [100%NPK + FYM + S_{30}+ Zn_5 +*Azotobacter* + PSB]. Maximum benefit cost ratio (B:C ratio) 2.26 and 2.08 were recorded under treatment T_7 [100 % NPK + Zn_5]. The maximum cost of cultivation during first year is ₹ 53805and second year is ₹ 59816 were recorded under treatment T_{10} [100 % NPK + S_{40} + Zn_5 + Fe_{10} + Azotobacter + PSB + 5 ton FYM]

Key Words: *Azotobacte*r,Economics, FYM, Phosphorous, PSB, Wheat and Yield.

Introduction

Wheat being an energy rich winter cereal contributes around 35% to the food grain basket of the country. Globally wheat (*Triticum aestivum* L.) is grown in 124 countries and occupied an area of about 215 million hectares with a production of 734.50 mt. of grain during 2019-20 **(Anonymous, 2020).** In India the area under wheat increased since the start of green revolution in 1967 and the production and productivity also increased. The area under wheat increased from 12.8 mha. In 1966-67 to 31.45 mha. in 2019-20. In this period production has also increased from 11.4 to 107.59 mt. and the productivity was increased from 887 to 3421 kg ha^{-1} **(Anonymous, 2020).**Wheat (*Triticum aestivum L.*) is one of the major cereal crops with a

Comment [D1]: Consider replacing this references.

Comment [D2]: Refer from my earlier comments unique protein, which is consumed by humans and is grown around the world in different environments **(Abedi*et al.*, 2010**). Wheat is foremost among cereals as a main source of carbohydrates and protein for both human beings and animals; contains starch (60-90%), protein (11-16.5%), fat (1.5-2%), inorganic ions(1.2-2%) and vitamins (B complex and vitamin E) **(Rueda-Ayala *et al.*, 2011)**.

In recent year the food grain production have been stagnated or even declined for both rice and wheat crops **(Dawe and Dobermann, 1999)** and there has been a wide gap between the target and actual production (**Pathak *et al*.,2003**). There are many reasons of low productivity of wheat out of which imbalance and excess fertilizer application is major one and changes in physico-chemical composition of the soil, a depletion and diminution in bioavailability of soil nutrients, a scarcity of good groundwater, buildup of pests and attack of various diseases of wheat greatly affected its yield and quality. Injudicious application of chemical fertilizers not only harms the biological power of soil but also decreases the soil fertility and crop productivity **(Parewa*et al*. 2014)**. Thus, integrated nutrient management advocates balanced and conjoint use of inorganic fertilizer, organic manure, and bio-inoculants in order to maintenance or adjustment of soil fertility and plant nutrient supply to an optimum level for sustaining desired crop productivity (**Rakshit*et al*. 2008**).

Nitrogen (N) is major factor for yield of wheat. The efficiency of wheat cultivars to N use has become increasingly important to allow reduction in N fertilizer use without decreasing yield. Wheat is an important cereal crop and requires a good supply of nutrients especially nitrogen for its growth **(Mandal *et al*., 1992)** and yield (**Krylov and Pavlov, 1989**). Nitrogen rate, type of nitrogen, and timing of its application are important factors to increase wheat yield **(Garrido-Lestache*et al*., 2005).** Some studies showed that N fertilization increases the total quantity of flour proteins, resulting in an increase in both gliadins and glutenin (**Dupont and Altenbach 2003).**

Phosphorus is essential for enhancing seed maturity and seed development (**Ziadi*et al.* 2008**). Phosphorus plays a significant role in several vital functions such as photosynthesis, transformation of sugar to starch, protein information, nucleic acid production, nitrogen fixation and formation of oil. It is also, the part of all biochemical cycles in plants (**Mehrvarz and Chaichi, 2008**).

Potassium (K^+) is of unusual significance because of its live role in biochemical functions of the

plant like activating various enzymes, improvement of protein, carbohydrates and fat concentration, developing tolerance against drought and resistance to frost, lodging, pests and disease attack. Therefore, potassium known as "quality element" and it was considered as a key factor in crop production (**Moussa, 2000**). It is thus necessary to devise a fertilizer technology facilitating use of NPK in apt combination for enhancing wheat yield **(Jabbar *et al*., 2009**).
Zinc is also reported as an important micronutrient for wheat production because it is required in a large number of enzymes and plays an essential role in DNA transcription. . It is reported that high amount of zinc is contained in pollen and mostly zinc is inverted to seed only during seed formation and an application of zinc improves grain formation **(Choudhary *et al*., 2007).**

Generally, crops needs less sulphur like cereals, still start suffering more and more from sulphur deficiency even there are some crops which need more sulphur as well. The baking properties of wheat and the biological value of proteins can also be improved by increasing sulphur fertilization which has reported many times **(Marschner, 1997; Jarvan*et al*., 2006).**

Judicious use of FYM with chemical fertilizers improves soil physical, chemical and biological properties and improves the crop productivity **(Sharma *et al*., 2007).** Application of organic manures may also improve availability of native nutrients in soil as well as the efficiency of applied fertilizers **(Sawrup,2010).**

The need of the hour is to evolve an integrated plant nutrient supply system, comprising balanced use of chemical fertilizer, organic manures and bio-fertilizers. An improvement in crop performance might be attributed to the N_2 -fixing and phosphate solubilising capacity of *Azotobacter* as well as the ability of these microorganisms to produce growth promoting substances. *Azotobacter* and graded doses of nitrogen increase phosphorus and potassium uptake by plants significantly Wheat poses problem for the establishment of*Azotobacter* in its rhizosphere. The inoculation of crop plants with bacterial preparation is recommended because a selective and compatible strain is supposed to accelerate plant growth. Phosphate solubilizing bacteria (PSB) as bio-fertilizers have been found effective in solubilizing the fixed soil P and applied phosphates resulting in higher crop yields (**Panhwar*et al*., 2014).**

Availability of iron plays a critical role in wheat crop productivity and economics. Ensuring an adequate supply of iron to wheat plants is essential for chlorophyll formation, photosynthesis, nutrient uptake, stress resistance, grain development, and overall yield. Iron deficiency can lead to decreased yield, lower grain quality, and additional costs associated with corrective measures. Balancing the costs of iron fertilizer application with the potential economic benefits of improved yield and grain quality is an important consideration for wheat farmers. (**Saquee *et al.*, 2023)**

Resources and Methods

Experimental Site

The experiment was conducted during *rabi* season of 2020-21 and 2021-22 at student's Instructional farm, C.S.A. University of Agriculture and Technology, Kanpur Nagar (U.P.). The field was well levelled and irrigated by tube well. The farm is situated at main campus of the university, in the west northern part of Kanpur city under sub-tropical zone in v^{th} agroclimatic zone (central plain zone).

EdaphicCondition

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. Analytical data of the experimental soil and method employed in the estimation was given in the Table-1

Table No. 1: Analytical data of the experimental soil (pre-sowing)

S. No.	**Soil characters**	**Value**		**Method employed**
		2021-22	**2022-23**	
1.	pH (1:2.5 soil water suspension)	8.14	8.15	Glass electrode pH meter **(Jackson, 1973)**
2.	EC (dsm^{-1}) (1:2.5 soil water suspension)	0.45	0.46	Conductivity bridge **(Jackson, 1973)**
3	Mechanical analysis			Hydrometer Method (**Bouyoucos, 1962**)
i	Sand (%)	60.92	60.40	
ii	Silt (%)	21.71	22.21	
iii	Clay (%)	17.37	17.29	
iv	Texture	Sandy loam	Sandy loam	
4.	Organic carbon (%)	0.35	0.36	Chromic acid digestion **(Walkley and**

				Black, 1934)
5.	Available N (kg ha^{-1})	178.16	180.56	Alkaline permanganate method **(Subbiah and Asija, 1956)**
6.	Available P (kg ha^{-1})	13.04	13.21	Olsen's calorimetrically method **(Olsen *et al.*, 1954)**
7.	Available K (kg ha^{-1})	129.54	132.42	Flame photometer Ammonium acetate extract **(Hanwey and Heidel, 1952)**
8.	Available S (kg ha^{-1})	15.98	16.02	Turbidimetric (0.15 % $CaCl_2$) method **(Chensin and Yien, 1950)**
9.	Available Zn (mg kg^{-1})	0.420	0.421	DTPA extraction (AAS) **Lindsay and Norvell (1978)**
10.	Available Fe (mg kg^{-1})	10.38	10.41	DTPA extraction (AAS) **Lindsay and Norvell (1978)**

Detail of treatments and design

The 11 treatments combination of nutrient management practices of inorganic fertilizer (Urea, DAP, MOP, Elemental sulphur, Zinc oxide and Iron oxide), Organic manure (FYM) and Biofertilizer (*Azotobacter* and PSB). Experiment was laid out in randomized block design with three replications.

Table -2: detail of the treatment combinations:

S. No.	Code	Treatment combinations
1.	**T_1**	Control
2.	**T_2**	100% NPK
3.	**T_3**	100 % NPK + 5 ton FYM
4.	**T_4**	100 % NPK + PSB + Azotobacter
5.	**T_5**	125 % NPK + PSB + Azotobacter + 5 ton FYM
6.	**T_6**	100 % NPK + S_{40}
7.	**T_7**	100 % NPK + Zn_5
8.	**T_8**	100 % NPK + S_{40} + Zn_5
9.	**T_9**	100 % NPK + S_{40} + Zn_5 + Fe_{10}

10.	**T_{10}**	100 % NPK + S_{40} + Zn_5 + Fe_{10} + Azotobacter + PSB + 5 ton FYM
11.	**T_{11}**	125 % NPK

Crop Husbandry

A pre-sowing irrigation (Paleva) was done in the experimental field with an object to get optimum moisture conditions for attaining good germination. At proper tilth, one ploughing with tractor drawn mould bold plough was done followed by two ploughings by cultivator. HalfdoseofNitrogentogetherwithfulldoseofPhosphorus,Potashwereappliedas basal at the time of sowing in the form of Urea, DAP and MOP respectively.Remaininghalfdoseofnitrogenwastopdressedintotwosplitdosesat30and 55daysaftersowing(DAS). The sowing of seeds of wheat cv. HD-2967 was done by linesowing by hand at 2-3 cm depth of soil and with line to line spacing of 22.5 cm to maintainuniform plant population. Application of FYM and Soil treatment with *Azotobacter* and PSB was done.

Harvesting and threshing: the crop was harvested at maturity and was allowed to dry in sun. Separate bundles were made for each plot and weighted. The after drying harvest was threshed manually.

Data Collection

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.

Biological yield (q ha^{-1})

Grain yield and Stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield

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 2021-22 and 2022-23.

Cost of cultivation (₹ 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 (₹ 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 (₹ ha^{-1}):

It was calculated by taking the income from the grain and straw produced on the basis of market rates. The yield of chickpea crop was converted into gross return in rupees per hectare on the basis of current price of the produce

$$\textbf{Gross return } (₹\,\mathbf{ha^{-1}}) = \textbf{ Total income from grain and straw yield}$$

Net return (₹ ha^{-1})

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

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

Benefit Cost ratio (B:C)

Net income of each treatment was divided by cultivation cost of respective treatment and cost benefit ratio was recorded. There was calculated with the help of following formula.

$$\boldsymbol{Benefit{:}cost\ ratio} = \frac{\boldsymbol{Net\ Return}\ (₹\,\boldsymbol{ha^{-1}})}{\boldsymbol{Cost\ of\ cultivation}\ (₹\,\boldsymbol{ha^{-1}})}$$

Statistical analysis:

The growth parameters and yields were recorded and analyzed as per Gomez and Gomez (1984) the tested at 5% level of significance to interpret the significant differences.

Result and Discussion

Productivity Parameters

It is visualized from the data given in Table-3 & Table-4 clearly indicate that among the productivity parameters viz. grain yield (q ha^{-1}), straw yield (q ha^{-1}) and biological yield (q ha^{-1}) significantly increase due to the application of NPK, Zinc, Iron, Sulphur, FYM, *Azotobacter* and PSB. Grain yield varied from 18.87 to 49.27 q ha^{-1}, straw yield varied from 29.15 to 65.34 q $ha^{-1}$and biological yield varied from 48.02 to 104.63 q ha^{-1}on pooled basis. The maximum grain yield (49.93q ha^{-1}), straw yield (67.63q ha^{-1}) and biological yield (114.61 q ha^{-1}) were recorded in the treatment T_{10} [100 % NPK + S_{40} + Zn_5 + Fe_{10} + Azotobacter + PSB + 5 ton FYM] during the second year (2022-23) of experimentation. The minimum grain yield (17.90q ha^{-1}), straw yield (26.87 q ha^{-1}) and biological yield (44.77 q ha^{-1}) was recorded in the treatment T_1 [control] during the first year (2021-22) of experimentation. The surge in seed and stover yields under adequate nutrients supply might be attributed to mainly to the collective effect of a greater number The spikelet ear^{-1}, grain $ear^{-1}$and 100 grain weight (gm), which was the result of improved translocation of photosynthates from source to sink ultimately yield is increased. The increase in productivity under adequate nutrients supply mainly due to more yield attributes ultimately resulted more grain yield. Grain, straw and biological yield of wheat significantly increased due to FYM application over their controls. Application of *Azotobacter* and PSBfurther increased grain & straw yield of wheat significantly over without application of *Azotobacter* and PSB. Inoculation of Azotobacter and PSB further increased grain & straw yield of wheat significantly over without inoculation. It may due to treatment of soil with bio-inoculant which fix atmospheric nitrogen and increased the supply of other nutrients to plants and ultimately increased grain and straw yield of wheat. These results also confirms the findings of **Singh and Jat (2016)**, **Kumar *et al.* (2022),and Sachan *et al.* (2022)**

The integrated use of nutrient application did not significantly affect the harvest index. Harvest index was varied from 39.34 – 41.04 % on pooled basis. Maximum harvest index (43.49 %) was associated with the treatment T_{10} [100 % NPK + S_{40} + Zn_5 + Fe_{10} + Azotobacter + PSB + 5 ton FYM]during the first year (2021-22) of the experimentation. While the minimum harvest index (38.69 %) was recorded under the treatment T_1 [Control] during the second year of experimentation. These results also confirms the findings of**Verma *et al.* (2022)**,**Sirohiya *et al.* (2022) and Kumar *et al.* (2022).**

Economics

Economic viability is a function of gain or loss. Any practice in order to be economical viable must have a substantial balance over its cost. In order to assured profitability net return and B: C ratio was worked out.While we study the economics of the wheat cultivation during the both years of experimentation, it can be concluded that all the economics parameters such as gross return, net return and benefit cost ratio except cost of cultivation were significantly affected by the application of NPK, Zinc, Iron, Sulphur, FYM, *Azotobacter* and PSB. The data extracted from the Table 4 and Table 5 it can be resulted that the maximum gross return (₹ 141127) was recorded in the treatment under T_{10} [100 % NPK + S_{40} + Zn_5 + Fe_{10} + Azotobacter + PSB + 5 ton FYM]during the second year (2022-23) of experimentation. The minimum gross return (₹ 54162) was recorded in the treatment T_1 [control] during the first year (2021-22) of experimentation. Maximum net return (₹ 89209) was recorded in the treatment T_9 [100% NPK + S_{40} + Zn_5 + Fe_{10}] during the first year (2021-22) of experimentation. The minimum net return (₹ 23511) was recorded in the treatment T_1 [control] during the first year (2021-22) of experimentation. Similarly, Maximum B:C ratio (2.26) was recorded in the treatment T_7 [100% NPK + Zn_5] during the first year (2021-22) of experimentation. The minimum B:C ratio (0.76) was recorded in the treatment T_1 [control] during the second year (2022-23) of experimentation. In the similar pattern, in case of cost of cultivation it can concluded that the maximum cost of cultivation (₹ 59816) was found in the treatment T_{10} [100%NPK + FYM + S_{30}+ Zn_5 +*Azotobacter* + PSB] during the second year of experimentation and minimum cost of cultivation(₹ 30651) was recorded in the treatment T_1 [control] during the first year (2021-22) of experimentation. If it is economically viable in modern farming maximum profit is more important than maximum profit the real comparison of different treatment can only judge on the basis of economic viability. The cost and gross return varied markedly due different application of inorganic, organic and bio-inoculant nutrients which ultimately influence the net return and B:C ratio. The consequences of the current investigation are additionally in concurrence with the investigation of **Dwivedi*et al.* (2014),Patra *et al.* (2019),Verma *et al.* (2022)and Gupta *et al.* (2022)**

Conclusion

The study showed that the application of NPK, Zinc, Sulphur, FYM, *Azotobacter* and PSB resulted in higher grain yield of wheat as well as higher net returns and B:C ratio; thus, it will help in uplifting the socioeconomic status of the farmers. Application of NPK, Zinc, Iron, Sulphur, FYM, *Azotobacter*and PSB deserves a special attention for increasing productivity and profitability of wheat.

Table-3: Effect of different treatment combinations on productivity parameters of wheat

Treatments	Grain Yield (q ha^{-1})			Straw Yield (q ha^{-1})		
	2021-22	**2022-23**	**Pooled**	**2021-22**	**2022-23**	**Pooled**
T_1	17.90	19.84	18.87	26.87	31.43	29.15
T_2	38.90	41.78	40.34	55.24	60.88	58.06
T_3	42.23	42.29	42.26	58.06	62.63	60.35
T_4	40.96	41.89	41.43	57.17	61.21	59.19
T_5	42.31	42.98	42.65	59.68	63.56	61.62
T_6	42.58	43.56	43.07	61.88	64.76	63.32
T_7	42.95	45.08	44.02	61.96	65.01	63.49
T_8	44.35	45.19	44.77	62.01	65.53	63.77
T_9	45.90	47.16	46.53	62.86	66.63	64.75
T_{10}	48.60	49.93	49.27	63.15	67.53	65.34
T_{11}	42.49	43.36	42.93	59.79	63.61	61.70
SE(m) ±	**0.31**	**0.34**	**0.39**	**0.27**	**0.23**	**0.39**
C.D. at 5 %	**0.93**	**1.00**	**1.24**	**0.80**	**0.68**	**1.22**

Table-4: Effect of different treatment combinations on productivity parameters of wheat

Treatments	Biological yield (q ha^{-1})			Harvest Index (%)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	44.77	51.27	48.02	39.98	38.69	39.34
T_2	94.14	102.66	98.40	41.32	40.70	41.01
T_3	100.29	104.92	102.61	42.11	40.31	41.21
T_4	98.13	103.10	100.62	41.74	40.63	41.18
T_5	101.99	106.54	104.27	41.48	40.34	40.91
T_6	104.46	108.32	106.39	40.76	40.21	40.49
T_7	104.91	110.09	107.50	40.94	40.95	40.94
T_8	106.36	110.72	108.54	41.70	40.81	41.26
T_9	108.76	113.79	111.28	42.20	41.44	41.82
T_{10}	111.75	117.46	114.61	43.49	42.51	43.00
T_{11}	102.28	106.97	104.63	41.54	40.53	41.04
SE(m) ±	**0.58**	**0.57**	**0.64**	**0.08**	**0.12**	**0.23**
C.D. at 5 %	**1.73**	**1.67**	**2.02**	**NS**	**NS**	**NS**

Table-5: Economic study of wheat as affected by different treatment combinations

Treatment	Cost of cultivation (₹ / ha)			Gross return (₹ / ha)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	30651	33405	32028	54162	58836	56499
T_2	37904	40658	39281	115495	120715	118105
T_3	45404	50658	48031	124046	122793	123419.5
T_4	38764	41518	40141	120915	121735	121325
T_5	48078	53332	50705	125338	124741	125039.5
T_6	42604	45922	44263	127271	120630	123950.5
T_7	39315	42132	40723.5	128198	129843	129020.5
T_8	44015	47396	45705.5	130998	130376	130687
T_9	45445	48956	47200.5	134654	135006	134830
T_{10}	53805	59816	56810.5	140190	141127	140658.5

T_{11}	39718	42472	41095	125771	125537	125654

Table-6: Economic study of chickpea as affected by different treatment combinations

Treatments	Net return (₹ / ha)			B:C ratio		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	23511	25431	24471	0.77	0.76	0.77
T_2	77591	80057	78824	2.05	1.97	2.01
T_3	78642	72135	75388.5	1.73	1.42	1.58
T_4	82151	80217	81184	2.12	1.93	2.03
T_5	77260	71409	74334.5	1.61	1.34	1.48
T_6	84667	74708	79687.5	1.99	1.63	1.81
T_7	88883	87711	88297	2.26	2.08	2.17
T_8	86983	82980	84981.5	1.98	1.75	1.87
T_9	89209	86050	87629.5	1.96	1.76	1.86
T_{10}	86385	81311	83848	1.61	1.36	1.49
T_{11}	86053	83065	84559	2.17	1.96	2.07

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