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SOIL SCIENCE

Effect of Integrated Nitrogen Management on Soil Physico-chemical Properties, Growth, Yield Attributes, Yield and Quality of Wheat (*Triticum aestivum* L.)

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ABSTRACT

A field experiment conducted during five consecutive *rabi* seasons (2016-17 to 2020-21) at research farm of R.K. (P.G.) College, Shamli (U.P.), with three replications under split-split plot design. FYM levels (0, 5, 10 t FYM/ ha) were taken as main plot, three N levels (40, 80, 120 kg N/ ha) as sub plot and four biofertilizer treatments (Control, *Azotobacter*, *Azospirillum*, *Azotobacter* + *Azospirillum*) as sub-sub plot. 10 t FYM/ ha resulted decrease in bulk density from 1.23 Mg/M^3 to 1.18 Mg/M^3. Highest WHC (0.35 Kg/ Kg soil), organic carbon (0.91%), CEC {10.59 Cmol (P$^+$)/ Kg soil} and available N (225.3 Kg N/ ha) noticed with 10 t FYM/ ha. The plots receiving 10 t FYM/ ha maintained 24.78, 24.76, 54.61 and 67.56 percent higher effective tillers, grain yield per spike, biological and grain yield/ ha, respectively. The plants with 120 kg N/ ha, produced 31.83 % higher biomass and 31.46 % higher grain yield over 40 kg N/ ha. Highest protein content (13.25%) and protein yield (785.72 kg protein/ ha) was registered with 10 t/ ha FYM. Inoculation with *Azotobacter* + *Azospirillum* had 7.06 % higher protein in their grains over uninoculated control. Application of 10 ton FYM/ ha resulted 46.35 and 24.56 % higher net return over 0 ton and 5 ton FYM/ ha, respectively. Highest gross return (₹ 112091/ ha), net return (₹ 76343/ ha), output: input (3.14) and benefit: cost ratio (2.14) was analyzed with 120 kg N/ ha. *Azotobacter* + *Azospirillum* resulted, 34.85% higher net return over no inoculation.

HIGHLIGHTS

- Long term FYM and biofertilizer improved soil environment
- Increased soil fertility, productivity and produce quality
- Reduced cost and increased farm profit.

Keywords: Biofertilizers, FYM, INM, Quality, Wheat, Yield

Wheat (*Triticum aestivum* L.), is the most important among all cereals used as a food grain in the world, covers an area of 215.90 million ha with production of 765.7 million tonnes. In India, wheat is cultivated in almost in all parts of the country and occupies 31.45 million ha with the production of 107.6 million tonnes with an average productivity of 3421 kg/ ha and contributes 12 percent to the total wheat production of the world (Anonymous 2019-20).

The agricultural scenario of India has completely changed due to modern intensive agriculture with high doses of fertilizer and high yielding varieties of crops. High yielding varieties has no doubt

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removed starvation from the world. But require high quantity of nutrients. Meeting such increased nutrients demand through fertilizers, has resulted several threats to agriculture *i.e.* environmental degradation, gradual depletion in soil nutrients pool, decline in soil fertility and an overall increase in the cost of cultivation. A wide gap (currently 10-12 Million tons) exists between annual nutrient removal and addition. To minimize the negative nutrient balance of about 10-12 million tons of NPK, the integrated nutrient supply system should be popularized. To fill the gap between demand and supply of nutrients, use of indigenous sources like FYM and biofertilizers should be encouraged. The FYM supplies all the nutrients and improve the physico- chemical and biological properties in respect of crop growth and there by increases overall soil fertility and productivity. It has been recognized that the soil contains certain free living bacteria, capable of fixing atmospheric nitrogen non symbiotically. Biofertilizers *i.*e. *Azotobactor* and *Azospirillum* alone or in combination have great prospect for increasing the productivity of cereals. The presence of *Azotobactor* and *Azospirillum* besides fixing atmospheric nitrogen also synthesize and secret certain biologically active compound such as nicotinic acid, panthonic acid, biotin and gibberellins, which stimulates the seed germination and overall growth of the crop Mishustin, (1970).

Present investigation was carried out to evaluate the long term impact of integration of FYM, inorganic N levels and biofertilizer inoculations on soil environment, growth, yield and produce quality in wheat (*Triticum aestivum* L.) and also to assess the inorganic nitrogen substitution capacity, and economic feasibility of organics and biofertilizers in wheat.

MATERIALS AND METHODS

A field experiment was conducted during consecutive five *Rabi* seasons from 2016-17 to 2020-21 on sandy loam soil at research farm of R.K. (P.G.) College, Shamli (U.P.). A composite representative soil sample was collected from the experimental field prior to start of the experimentation and analyzed for different physico-chemical properties and available N in the soil. The soil of the experimental field was medium in organic carbon, low in total and available nitrogen, and medium in P and K, and was slightly alkaline in reaction. The soil was also analyzed plot wise to find long term impact of different treatments on soil physico-chemical properties after the harvest of crop in the year 2020-21.

Treatments comprised of three FYM levels (0,5 & 10 t FYM/ ha) as main plots, nitrogen levels (40,80,120 kg N/ ha) as sub plot and bio-fertilizer inoculation (no-inoculation, *Azotobactor, Azospirillum, and Azotobactor + Azospirillum)* as sub-sub-plot treatments were replicated thrice and laid out in split-split plot design. The same undisturbed layout was used for all five years of experimentation. Farm yard manure (0.46 % N and 14.52 % organic carbon) was well incorporated in soil by mixing. The seeds were inoculated with carrier-based *Azotobactor crococum* and *Azospirillum lipoferum* strains @200 g/ ha. Nitrogen through urea and biofertilizers (*Azotobactor* and *Azospirillum)* were applied according to the treatment combinations. Recommended dose of phosphorus (60 kg P_2O_5/ ha) and potassium (40 kg K_2O/ ha) were basally applied to all the plots through single super phosphate and muriate of potash, respectively. Wheat *cv*. HD 2967 was sown @ 100 kg/ ha. Growth and yield data of the crop and soil samples were collected and analyzed for different parameters by adopting standard procedures. The cost of cultivation under various treatments was estimated on the basis of prevailing rates for input in Shamli (Uttar Pradesh, India). The input costs of all the items like tillage operation, costs of seed, herbicide treatment application, chemical fertilizers, and the hiring charges of human labour and machines for land preparation, irrigation, fertilization, harvesting and threshing. The benefit: cost ratios were calculated for each treatments applied in the system as the ratios of net returns to cost of cultivation. Recorded observations were statistically analyzed according to Fedrer, (1967) and Gomez & Gomez, (1984).

RESULTS AND DISCUSSION

Effect on soil physico-chemical properties

Long term application of FYM, nitrogen and biofertilizers had significant effect on different physico-chemical properties of the soil (Table 1, Fig. 1 and 2). Application of 10 ton FYM/ ha resulted significant decrease in overall bulk density of soil

Table 1: Long term effect of different treatments on soil physico-chemical properties and available nitrogen status

Treatment	Soil physical parameters						Soil chemical parameters					
	Bulk density (Mg/M^{-3})		WHC (Kg/Kg soil)		Soil p^H		Organic carbon (%)		CEC (Cmol (P$^+$) / Kg Soil)		Available N (Kg/ ha)	
	Initial (2016-17)	Final (2020-21)	Initial (2016-17)	Final (2020-21)	Initial (2016-17)	Final (2020-21)	Initial (2016-17)	Final (2020-21)	Initial (2016-17)	Final (2020-21)	Initial (2016-17)	Final (2020-21)
FYM level (t / ha)												
0	1.23	1.23	0.30	0.29	7.4	7.4	0.60	0.68	9.87	9.86	187.0	182.5
5	1.23	1.19	0.30	0.32	7.4	7.3	0.60	0.73	9.87	10.13	187.0	220.6
10	1.23	1.18	0.30	0.35	7.4	7.1	0.60	0.91	9.87	10.59	187.0	225.3
CD (P=0.05)	—	0.03	—	0.02	—	NS	—	0.19	—	0.61	—	13.6
N level (kg N/ ha)												
40	1.24	1.24	0.31	0.31	7.4	7.4	0.60	0.65	9.87	9.88	187.0	164.5
80	12.4	1.23	0.31	0.31	7.4	7.3	0.60	0.70	9.87	9.86	187.0	172.6
120	1.24	1.23	0.31	0.30	7.4	7.2	0.60	0.89	9.87	9.87	187.0	186.7
CD (P=0.05)	—	NS	—	NS	—	NS	—	0.15	—	NS	—	14.4
Biofertilizer												
Control	1.24	1.23	0.31	0.31	7.4	7.3	0.6	0.68	9.87	9.87	187.0	184.2
Azotobacter	1.24	1.20	0.31	0.33	7.4	7.2	0.60	0.72	9.87	10.02	187.0	199.6
Azospirillum	1.24	1.21	0.31	0.33	7.4	7.2	0.60	0.71	9.87	10.06	187.0	195.2
Azotobactor + Azospirillum	1.24	1.20	0.31	0.34	7.4	7.1	0.60	0.85	9.87	10.14	187.0	204.5
CD (P=0.05)	—	0.02	—	0.02	—	NS	—	0.18	—	NS	—	15.3

**FYM = Farm Yard Manure, NS= Non significant, Initial (2016-2017), Final (2020-2021).*

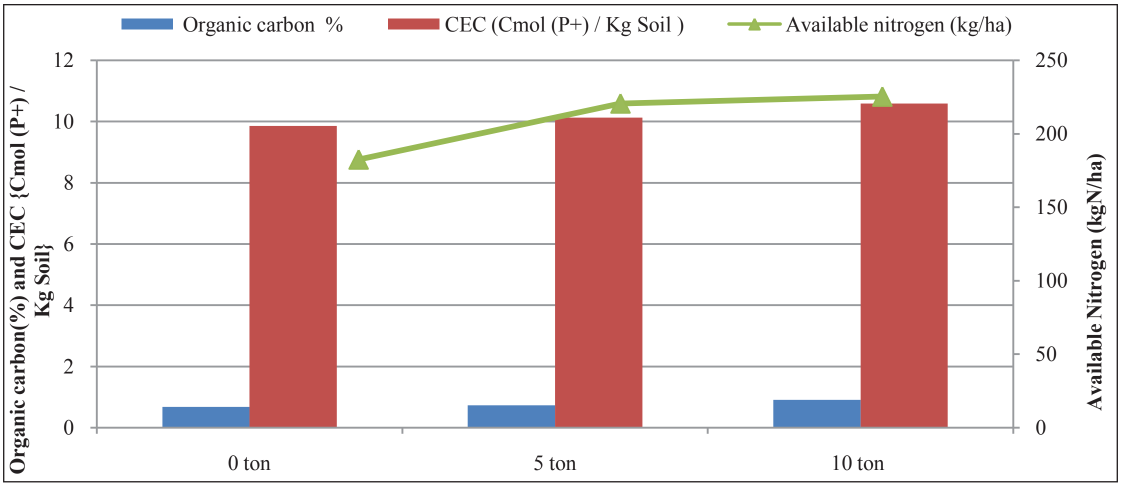

Fig. 1: Organic carbon, CEC and available soil nitrogen as influenced by FYM levels

from 1.23 Mg/M^3 to 1.18 Mg/M^3 (Table 1, Fig. 1). Due to five years continuous application of 10 ton FYM, the WHC increased from 0.30 to 0.35 kg water/ kg soil, soil organic carbon increased from 0.60 to 0.91%, CEC increased from 9.87 to 10.59 Cmol (P$^+$)/ kg soil and available nitrogen status also increased from 187.0 to 225.3 kg N/ ha. Highest WHC (0.35Kg/ Kg soil), organic carbon (0.91%) cation exchange capacity (10.59 Cmol (P$^+$) /Kg soil) and available N (225.3 Kg N/ ha) was noticed with 10 ton FYM/ ha. Cation exchange capacity and available nitrogen might was attributed to the gradual increase in overall humus content due to continuous addition of FYM. Whereas, a significant reduction in bulk density with 10 ton FYM/ ha might was due to overall increase in organic carbon % of soil, as organic matter is usually lighter in weight than soil separates. Similar results were observed by Shafi, *et al.* (2012).

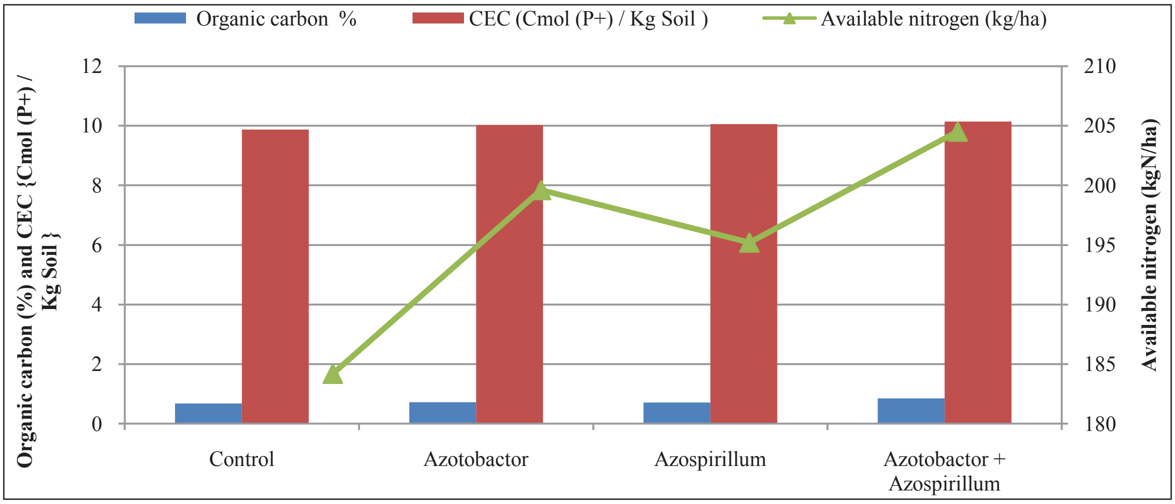

Fig. 2: Organic carbon, CEC and Available soil nitrogen as influenced by biofertilizers

Amongst nitrogen levels, highest value of organic carbon (0.89%) and available nitrogen (186.7 Kg N/ ha) was determined with 120 Kg N/ ha. However, bulk density, water holding capacity, soil p^H and cation exchange capacity could not cross the level of significance (Table 1, Fig. 2). Higher value of organic carbon with 120 Kg N could be due to higher root biomass production and its incorporation. Whereas, higher level of available N might was because of continuous addition of higher dose of N in the soil. The result is in accordance to the finding of Rathwa, *et al.* (2018).

Biofertilizers also had significant influence on bulk density, water holding capacity, organic carbon and available N level in the soil. However, soil p^H and cation exchange capacity remained statistically unchanged due to biofertilizers inoculation (Table 1). Highest water holding capacity (0.34 kg/kg soil), organic carbon (0.85%) and available nitrogen in soil (204.5 kg N/ ha) was determined with *Azotobacter* + *Azospirillum* inoculation. Joint inoculation of *Azotobacter* + *Azospirillum* resulted 9.6%, 25% and 11.02% higher WHC, organic carbon and available N in soil, respectively over no inoculation. The increase in water holding capacity and organic carbon content might was attributed to increased microbial population and an overall increase in higher underground biomass production. However, higher available N level in soil with *Azotobacter* + *Azospirillum* inoculation might was attributed to their joint effect on atmospheric nitrogen fixation inside the soil. The results confirm the findings of Mohanty, *et al.* (2015).

Growth parameters

FYM, nitrogen levels as well as biofertilizer inoculation had significant influence on different growth parameters of wheat (Table 2).

Amongst FYM levels, highest number of shoots (415/m^2 area at 60 DAS and 300/ m^2 at maturity), plant height (92.3 cm at 60 DAS and 125.6 cm at maturity), dry matter accumulation (640 g at 60 DAS and 1350 g/m^2 at maturity) per plant leaf area (420.7 cm^{2}at 60 DAS and 425.6 cm^2/plant at 90 DAS) and leaf area index (8.41 at 60 DAS and 8.51 at 90 DAS) was observed with 10 ton FYM/ ha, which registered its significant superiority over 0 ton FYM. The plant supplied with 10 ton FYM/ ha grew 25.43% tall and assimilated 32.35 percent higher biomass at maturity over no FYM application. Higher value of different growth parameter with 10 ton FYM/ ha could be attributed to favorable impact of FYM on different physico-chemical properties of soil and also due to supply of all the nutrients to the plants. The result confirms the findings of Dalvi and Bhilare (2015).

Nitrogen levels too had significant influence on growth traits of wheat (Table 2). Highest number of effective shoots (298 shoots/m^2), plant height (124.9 cm), dry matter accumulation 1346 g/m^2) at maturity, leaf area (423.3cm^2/plant) and leaf area index (8.59) at 90 DAS was recorded with 120 kg N/ ha. The difference between 120 kg N to 80 kg N/ ha against different growth parameters was non significant. The plants fertilized with 120kg N per hectare had 25.21% higher shoots, assimilated 30 percent higher biomass and grew 21.9 percent taller

Table 2: Effect of different treatments on number of shoots, plant height, dry matter, leaf area and LAI at different growth stages of wheat *cv*. HD 2967 (Pooled data of 5 years)

Treatment	Shoots/ meter^2		Plant height (cm)		Dry matter (g /m^2)		Leaf area (cm^2/plant)		Leaf Area Index	
	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest	60 DAS	90 DAS	60 DAS	90 DAS
FYM level (t / ha)										
0	340	240	76.3	100.13	550.3	1020	305.2	305.2	6.10	6.10
5	390	285	84.6	112.4	590.4	1260	365.6	398.3	7.31	7.59
10	415	300	92.3	125.6	640.3	1350	420.7	425.6	8.41	8.51
CD (P=0.05)	27.2	22.4	5.1	8.5	49.3	102	28.1	29.3	0.42	0.41
N level (kg N/ ha)										
40	335	238	74.6	102.4	545.3	1035	298.6	301.2	5.97	6.02
80	395	276	83.9	110.6	586.4	1251	355.3	362.4	7.10	7.25
120	406	298	91.6	124.9	635.6	1346	428.6	423.3	8.57	8.59
CD (P=0.05)	26.9	21.7	5.2	8.3	50.1	103	29.3	30.2	0.41	0.43
Biofertilizer										
Control	329	236	72.6	100.5	541.4	1055	299.4	301.6	5.98	6.03
Azotobacter	393	265	81.4	109.3	580.3	1231	328.3	329.7	6.56	6.59
Azospirillum	390	273	83.9	110.4	585.4	1245	329.6	331.4	6.59	6.63
Azotobacter + Azospirillum	425	290	91.4	123.9	625.7	1330	398.9	399.2	7.98	7.98
CD (P=0.05)	28.1	23.4	5.0	8.6	51.8	101	30.2	27.9	0.45	0.42

**FYM = Farm Yard Manure.*

than 40 kg N/ ha. Higher value of different growth parameter with 120 kg N/ ha might was due to adequate and ever supply of nitrogen which might have resulted higher synthesis of chlorophyll. Thus, plants maintained higher pace for photosynthesis grew tall and assimilated higher biomass. The result corroborates the findings of Tiwari *et al*. (2001).

Biofertilizers also had significant influence on growth parameters of wheat, Maximum number of shoots at maturity (290/m^2), plant height (123.9 cm), dry matter yield (1330 g/m^2), leaf area at 90 DAS (399 cm^2/plant) and leaf area index (7.98) was registered with joint inoculation with *Azotobacter* and *Azospirillum*. Similar trend of response against different growth parameter was registered at 60 DAS also. The plots jointly inoculated with *Azotobacter* + *Azospirillum* maintained 22.80% higher number of shoots at maturity and assimilated 15.57 and 26.06 percent higher biomass over no inoculation at 60 DAS and at harvest, respectively. The difference between *Azotobacter* to *Azospirillum* in respect of different growth parameters was non significant. Higher value of different growth traits of wheat with joint inoculation of *Azotobacter* + *Azospirillum* could be due to their combined effect on fixation of atmospheric nitrogen. Thus, plants might maintained higher amount of chlorophyll in their leaves even during later period of their life cycle and had higher value of different growth parameters. The result is in accordance to finding of Singh *et al*. (2016).

Yield attributes and yield

The data pertaining to yield attributes, yields and harvest index has been presented in table 3. Farm yard manure, N levels and biofertilizers inoculation had significant effect on different yield attributing characters as well as yields. Application of 10 ton FYM/ ha resulted maximum spikes (297 spikes/m^2), grain/ spike (46.2 grains), grain yield/spike (2.62 g), 1000-grain weight (42.6 g), biological (138.30 q/ ha), grain (59.30 q/ ha), straw yield (79.0q/ ha) as well as harvest index (0.43). However the differences for spikes/m^2 area, 1000-grain weight and harvest index between 10 ton FYM/ ha to 5 ton FYM/ ha could not cross the level of significance. The plots receiving 10 ton FYM/ ha maintained 24.78, 24.76, 54.61 and 67.56 percent higher effective tillers, grain yield per spike, biological and grain yield/ ha, respectively over 0 ton FYM. The higher value of different yield attributes with 10 ton FYM could be due to higher pace of growth due to ever supply of all the essential plant nutrients throughout the life cycle of the plant. Whereas, higher biological, grain and straw yield with 10 ton FYM might was attributed to higher value of different yield attributing characters of wheat. The results are in accordance to the finding of Naeem Sarwar, *et al*. (2021).

Nitrogen levels too, had significant influence on different yield attributing characters as well as on yield and recorded highest number of effective tillers (295/m^2), grains per spike (45.2 grains), grain yield per spike (2.60 g), biological (138.30 q/ ha), grain (59.95 q/ ha) and straw yield (78.35 q/ ha) with 120 kg N/ ha. However, highest harvest index (0.440) was registered with the application of 80 kg N/ ha, although it could not cross the level of significance. The difference between 120 kg N/ ha to 80 kg N/ ha for 1000-grain weight, was statistically non significant. The plants supplied with 120 kg N/ ha had 22.64 % higher grain yield/ spike, produced 31.83 % higher biomass and 31.46 percent higher grain yield over 40 kg N/ ha. (Table 3). The higher value of different yield attributes with 120 kg N/ ha could be due to ever and adequate supply of nitrogen to the plants which tended the plants to maintain higher pace of growth. Thus, the plants wore bigger ears with higher number of grains of bold size. However, higher biological, grain and straw yield with 120 kg N/ ha might was because of higher value of different yield attributing characters. The similar results were reported by Jat, *et al*. (2015).

Besides FYM and nitrogen levels, biofertilizer inoculation also had significant influence on different yield attributes and yield (Table 3). Highest number of effective tillers (282 tillers/m^2), number of grain/ spike (44.3 grains), grain yield per spike (2.53g), 1000-grain weight (41.69g), biological (132.40q/ ha), grain (55.21q/ ha) and straw yield (77.19 q/ ha) was registered with joint inoculation of *Azotobactor* + *Azospirillum*. Effect of biofertilizer inoculation on harvest index remained statistically non significant. The differences between *Azotobactor* and *Azospirillum* for different yield attributes and yields was non significant. The combined inoculation of *Azotobactor* + *Azospirillum* resulted 24.67 % higher biological, 21.10 % higher grain and 27.35 % higher straw yield over no inoculation. Higher value of different yield attributes due to joint inoculation of *Azotobactor* + *Azospirillum* could be due to its effect of maintaining higher available nitrogen through their atmospheric N-fixing ability in soil, whereas, higher value of biological, grain and straw yield could be attributed to its positive influence on different yield contributing characters. The result corroborates the findings of Naeem Sarwar, *et al*. (2021).

Quality parameters

Application of FYM, nitrogen as well as biofertilizer inoculation had significant influence on protein content as well as protein yield (Table 4). Highest protein content (13.25%) and protein yield (785.72 kg protein/ ha) was registered with 10 ton/ ha FYM followed by 12.17 percent protein and 611.66 kg protein/ ha with 5 ton FYM/ ha. The plants supplied with 10 ton FYM/ ha, assimilated 17.25 percent higher protein in their grains over no FYM application. Higher protein content with 10 ton FYM/ ha might was because of higher availability of nutrients (N, P, K and S) which are constituent for synthesis of protein. Whereas, higher protein yield was attributed to higher protein content and grain yield as well. The findings are analogous to the results of Manish Kakraliya and Rajesh Singh, *et al*. (2018).

Amongst nitrogen levels highest protein content as well as protein yield 12.39 and 742.78 kg protein content and protein yield/ ha, respectively was determined with 120 kg N/ ha. Higher protein content with 120 kg N/ ha might be due to ever and adequate supply of most dominating substrate (nitrogen) for the synthesis of protein. However, higher protein yield could be jointly attributed, to higher content of protein and grain yield with 120 kg N/ ha. The results are in accordance to findings of Jat, *et al.* (2015).

Biofertilizer inoculation also registered positive impact on protein content and protein yield (Table 4). Highest protein content (12.12%) and protein yield (669.14 kg protein/ ha) was analyzed under joint inoculation with *Azotobactor* + *Azospirillum*. The difference in respect of protein content and protein yield between *Azotobactor* and *Azospirillum* inoculation was non significant. The plants enjoying combined inoculation with *Azotobactor* + *Azospirillum* had 7.06 percent higher protein in their grains as compared to uninoculated control. Higher protein content with *Azotobactor* + *Azospirillum* could be due to additionally higher availability of nitrogen, which is major substrate for the synthesis of proteins. However, higher protein yield might be because of their respective higher grain yield.

Table 3: Effect of different treatments on yield attributes, yields and harvest index of wheat cv. HD 2967 (Pooled data of 5 years)

Treatment	Effective tillers / m^2	Grains / spike	Grain yield/ spike (g)	1,000- grain weight (g)	Biological yield (q/ ha)	Grain yield (q/ ha)	Straw yield (q/ ha)	Harvest index
FYM level (t / ha)								
0	238	37.3	2.10	39.61	89.45	35.39	54.06	0.40
5	282	40.4	2.41	41.9	118.23	50.26	67.97	0.43
10	297	46.2	2.62	42.6	138.30	59.30	79.00	0.43
CD (P=0.05)	17.93	3.02	0.18	2.02	9.73	2.83	4.39	0.012
N level (kg N/ ha)								
40	235	36.9	2.12	39.41	104.90	45.60	59.30	0.43
80	274	38.8	2.37	41.4	116.30	51.74	64.56	0.44
120	295	45.2	2.60	41.80	138.30	59.95	78.35	0.43
CD (P=0.05)	16.95	3.09	0.17	2.06	9.47	2.86	4.42	NS
Biofertilizer								
Control	232	36.8	2.09	38.91	106.20	45.59	60.61	0.42
Azotobacter	261	40.3	2.40	40.26	121.20	50.39	70.81	0.41
Azospirillum	267	41.2	2.41	40.39	120.39	51.21	69.18	0.42
Azotobacter + *Azospirillum*	282	44.3	2.53	41.69	132.40	55.21	77.19	0.41
CD (P=0.05)	18.29	3.07	0.19	2.10	9.86	2.91	4.69	NS

**FYM = Farm Yard Manure, NS= Non significant.*

Table 4: Effect of different treatments on nutrient uptake and quality parameters of wheat *cv.* HD 2967 (Pooled data of 5 years)

Treatment	Protein content (%)	Protein yield (kg/ ha)	Net return (₹/ ha)	Output input ratio (₹/₹)	Benefit cost ratio (₹/₹)
FYM level (t / ha)					
0	11.30	399.91	57919	2.83	1.87
5	12.17	611.66	68051	3.08	2.08
10	13.25	785.72	84767	3.47	2.48
CD (P=0.05)	0.60	40.98	—	—	—
N level (kg N/ ha)					
40	11.69	509.68	54314	2.56	1.64
80	11.89	615.19	65002	2.85	1.84
120	12.39	742.78	76343	3.14	2.14
CD (P=0.05)	0.61	42.44	—	—	—
Biofertilizer					
Control	11.32	516.08	55184	2.61	1.60
Azotobacter	11.63	508.09	65114	2.86	1.86
Azospirillum	11.64	596.08	65942	2.84	1.88
Azotobacter + *Azospirillum*	12.12	669.14	74416	3.08	2.08
CD (P=0.05)	0.62	40.36	—	—	—

**FYM = Farm Yard Manure.*

Economics

Farm yard manure, nitrogen as well as biofertilizers inoculation had significant influence on net return and output: input as well as benefit: cost ratio (Table 4; Fig. 3). Amongst FYM levels highest net return (₹ 84767/ ha), output: input (3.47) and benefit: cost ratio (2.48) was observed with 10 ton FYM/ ha followed by 5 ton FYM/ ha. Application of 10 ton FYM/ ha resulted 46.35 and 24.56 percent higher net return over 0 and 5 ton FYM/ ha, respectively. Higher net return, output: input and benefit: cost ratio with 10 ton FYM might was due to relatively higher grain and straw yield obtained with 10 ton FYM.

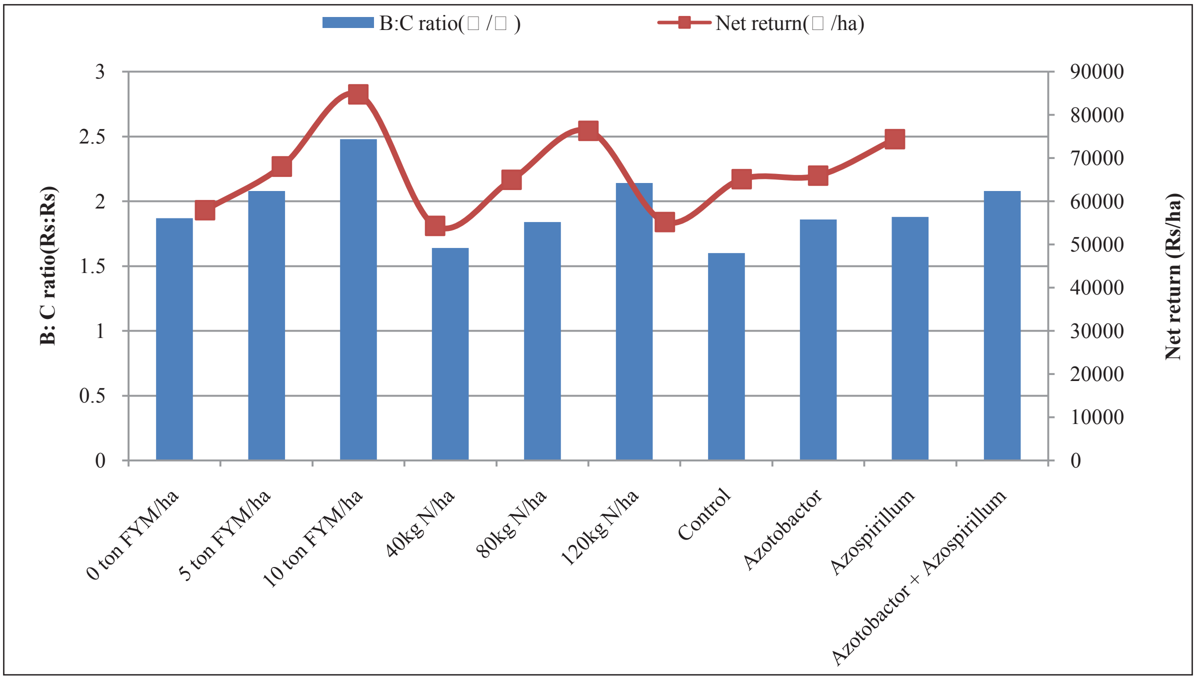

Fig. 3: Net return and B: C ratio as influenced by FYM, N levels and Biofertilizers

Similarly highest net return (₹ 76343/ ha), output: input (3.14) and benefit: cost ratio (2.14) was analyzed with 120 kg N/ ha. Application of 120 kg N/ ha resulted 40.55 and 30.48 percent higher net return and benefit: cost ratio over 40 kg N/ ha, respectively. Higher net return, output: input and benefit: cost ratio with 120 kg N/ ha was attributed to its higher grain and straw yield.

Biofertilizer inoculation too, exhibited significant influence on economics of production. Highest net return (₹ 74416/ ha), output: input (3.08) and benefit: cost ratio (2.08) was obtained under joint inoculation of *Azotobacter* + *Azospirillum*. The response of individual inoculation with either of biofertilizer strains was comparable to each other. Joint inoculation with *Azotobacter* + *Azospirillum* resulted, 34.85 percent higher net return over no inoculation. Higher economical return with Biofertilizer inoculation was due to their positive influence on grain and straw yields (Table 4, Fig. 3). Similar results were reported by Manish Kakralia and Rajesh Singh, (2018).

CONCLUSION

The above results indicate the significant influence of FYM, fertilizer–N application and biofertilizer inoculation on different physico-chemical properties of soils. After five years of continuous experimentations, water holding capacity, bulk density, organic carbon, CEC and available N status in soil was changed favorably. Besides, it resulted, higher quantity and quality of produce with relatively low cost, thus, help to attain higher farm profit. Hence, it can be concluded that FYM and biofertilizer inoculation could be proved a potential tool for substitution of inorganic nitrogen in wheat and would be a successful approach to maintain soil fertility for higher productivity.

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