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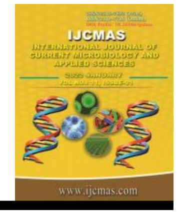

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Long Term Impact of Integrated Nitrogen Management Practices on Soil Environment, Nutrient Uptake, Produce Quality, Yield and its Economic Feasibility in Wheat (*Triticum aestivum* L.)

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A field experiment was conducted during *Rabi* seasons (2016-17 to 2020-21) at research farm of R.K. (P.G.) College, Shamli, with three replications under split-split plot design. FYM levels were taken as main plot, three N levels as sub plot and four biofertilizer treatments as sub-sub plot. Application of 10 ton FYM/ ha resulted significant decrease in bulk density from 1.23Mg/ M^3 to 1.18 Mg/ M^3. Joint inoculation with *Azotobacter* + *Azospirillum* resulted, 9.6, 25 and 11.02 percent higher WHC, organic carbon and available N in soil, respectively over no inoculation. The plots receiving 10 ton FYM/ ha maintained 24.76, 54.61 and 67.56 percent higher grain yield per spike, biological and grain yield/ ha, respectively over 0 ton FYM. Application of 120 kg N/ ha had 22.64, 31.83 and 31.46 percent higher grain yield/ spike, biomass and grain yield/ ha, respectively over 40 kg N. Highest protein (13.25%) was registered with 10 ton/ ha FYM. *Azotobacter* + *Azospirillum* had 7.06 percent higher protein over uninoculated control. Highest gross (₹ 112091/ ha), net return (₹ 76343/ ha) and benefit: cost ratio (2.14) observed with 120 kg N/ ha. *Azotobacter* + *Azospirillum* resulted, 34.85 percent higher net return over no inoculation.

Introduction

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 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. Koopmans and Goldstein (2001) stated that soil organic matter should be treated as a bank account. For sustainability it is important to add higher amount of organic matter and nutrients than its annual degradation/ removal. The FYM supplies all the nutrients and improve the physico-chemical and biological properties in respect of crop growth and there by increases the 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. Azotobacter* and *Azospirillum* alone or in combination have great prospect for increasing the productivity of cereals. The presence of *Azotobacter* 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, nutrient uptake, 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 (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 initial value of 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, *Azotobacter*, *Azospirillum*, *and Azotobacter* + *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 *Azotobacter crococum* and *Azospirillum lipoferum* strains @ 200 g/ ha. Nitrogen through urea and biofertilizers (*Azotobacter* 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 seed/ 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 U.P. (India).

The input costs of all the items *i.e.* 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 was taken on the basis of their prevailing prices in the year 2020-21. The benefit: cost ratios for each treatments was calculated as the ratios of net returns to cost of cultivation. Recorded observations were statistically analyzed according to statistically procedure evolved by 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 (Table1, Fig.1, Fig.2 and Fig.3). Application of 10 ton FYM/ ha resulted significant decrease in overall bulk density of soil from 1.23Mg/ M^3 to 1.18 Mg/ M^3 (Table1, 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 enhanced 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. Higher 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).

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 pH and cation exchange capacity could not cross the level of significance (Table1, 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 be 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 status in the soil. However, soil pH and cation exchange capacity remained statistically unchanged due to biofertilizers inoculation (Table1, Fig.3). Highest water holding capacity (0.34 kg/ kg soil), organic carbon (0.85%) and available nitrogen in the 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 underground biomass production. However, higher available N status in soil with *Azotobacter* + *Azospirillum* inoculation might was attributed to their joint effect on atmospheric nitrogen fixation inside soil. The result confirm the findings of Mohanty *et al.,* (2015).

Nutrient uptake

The data pertaining to nitrogen, phosphorus, potassium and sulfur uptake has been presented in table 2. Application of 10 ton FYM/ ha resulted highest uptake of nitrogen (140.3 kg N/ ha), phosphorus (30.2 kg P/ ha), potassium (94.2 kg K/ ha) and sulfur uptake (30.4 kg S/ ha) which was significantly higher over 0 and 5 ton FYM/ ha. The plots receiving 10 ton/ ha FYM had 37.01 percent higher nitrogen. 24.27 percent higher phosphorus, 49.76 percent higher potassium and 93.63 percent higher sulfur uptake over 0 ton FYM/ ha. Higher uptake of N, P, K and S with 10 ton/ ha FYM could be due to presence of these nutrients in FYM and also due to favorable effect of FYM on different physico-chemical and biological properties of soil in respect of availability of plant nutrients. The results are in accordance to the findings of Singh *et al.,* (2016).

Nitrogen levels too, had significant influence on the uptake of different nutrients (Table 2). Amongst nitrogen levels, highest uptake of N (142.8 kg N/ ha), P (29.2 kg P/ ha), K (90.1 kg K/ ha) and sulfur (28.3 kg S/ ha) was determined with 120 kg N, followed by 80 kg N/ ha. The difference between

120 kg N to 80 kg N/ ha in respect of phosphorus and sulfur uptake was non significant. Application of 120 kg N/ ha resulted 23.95 % higher nitrogen and 30 percent higher K uptake over 40 kg N/ ha. Significantly higher uptake of nitrogen with 120 kg N/ ha might was due to higher application of nitrogen. However higher phosphorus, potassium and sulfur uptake might was attributed to higher biomass production with 120 kg N/ ha. The results confirm the findings of Rathwa *et al.,* (2018).

Biofertilizer inoculation also had significant effect on uptake of different nutrients (Table 2). Highest uptake of nitrogen (140.2 kg N/ ha), phosphorus (30.2 kg P/ ha), potassium (85.0 kg K/ ha) and sulfur (27.4 kg S/ ha) was analyzed under combined inoculation of *Azotobacter* + *Azospirillum*. The differences for nutrient uptake between *Azotobacter* to *Azospirillum* remained statistically non significant. *Azotobacter* + *Azospirillum* inoculation resulted, 42.47 percent higher uptake of nitrogen over uninoculated control. Higher uptake of nitrogen with joint inoculation might was due to joint fixation of atmospheric nitrogen. However higher uptake of P, K and S could be due to secretion of hydrolytic enzyme by *Azotobacter* and *Azospirillum* which helped in solubilization of natively available complex substances containing these nutrients. Higher uptake of nutrients could also be attributed to higher level of biomass production with *Azotobacter* + *Azospirillum* inoculation. The result corroborates the findings of Singh *et al.,* (2016).

Quality parameters

Application of FYM, nitrogen as well as biofertilizer inoculation had significant influence on protein content as well as protein yield (Table2, Fig.4). Highest protein content (13.25%) and protein yield (785.72 kg protein/ ha) was registered with 10 ton FYM followed by 12.17 percent protein and 611.66 kg protein/ ha with 5 ton FYM/ ha. The plants supplied with 10 t 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 the 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, respectively was determined with 120 kg N/ ha. The difference between protein content between 80 kg N to 120 kg N/ ha was statistically non significant. 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, whereas, 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 (Table2, Fig.4). Highest protein content (12.12%) and protein yield (669.14 kg protein/ ha) was analyzed under joint inoculation with *Azotobacter* + *Azospirillum*.

The difference in respect of protein content and protein yield between *Azotobacter* and *Azospirillum* inoculation was non significant. The plants enjoying combined inoculation with *Azotobacter* + *Azospirillum* had 7.06 percent higher protein in their grains as compared to uninoculated control (Singh *et al.,* 2007). Increased protein content with *Azotobacter* + *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.

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 biofertilizer inoculation had markedly 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 (79.0 q/ 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 findings 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 (0.44) was registered with 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. 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 (2.53 g), 1000-grain weight (41.69 g), biological (132.40 q/ ha), grain (55.21 q/ ha) and straw yield (77.19 q/ ha) was registered with joint inoculation of *Azotobacter* + *Azospirillum*. Effect of biofertilizer inoculation on harvest index remained statistically non significant. The differences between *Azotobacter* and *Azospirillum* for different yield attributes and yields was non significant.

The combined inoculation of *Azotobacter* + *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 with joint inoculation of *Azotobacter* + *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).

Economics

Farm yard manure, nitrogen as well as biofertilizer inoculation had significant influence on cost of production, gross, net return and output: input as well as benefit: cost ratio (Table 4; Fig.4)

Amongst FYM levels highest cost of production (₹ 34200/ ha), gross return (₹ 118967/ ha), 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.

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

Treatment	Soil physical parameters						Soil chemical parameters					
	Bulk density (Mg/M^{-3})		WHC (Kg/Kg soil)		Soil pH		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)	Fina (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**
Azotobacter + 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).

Table.2 Effect of different treatments on nutrient uptake and quality parameters of wheat *cv*. HD 2967 (Pooled data of 5 years)

Treatment	N uptake (kg N/ha)	P uptake (kg P/ha)	K uptake (kg K/ha)	S uptake (kgS/ha)	Protein content (%)	Protein yield (kg/ha)
FYM level (t /ha)						
0	102.4	24.3	63.2	15.7	11.30	**399.91**
5	127.8	26.3	70.4	22.6	12.17	**611.66**
10	140.3	30.2	94.2	30.4	13.25	**785.72**
CD (P=0.05)	9.21	2.4	5.2	2.4	0.60	**40.98**
N level (kg N/ha)						
40	115.2	25.2	69.3	20.3	11.69	**509.68**
80	130.3	26.3	75.4	26.4	11.89	**615.19**
120	142.8	29.2	90.1	28.3	12.39	**742.78**
CD (P=0.05)	9.3	3.1	5.6	3.6	0.61	**42.44**
Biofertilizer						
Control	98.4	21.6	61.7	16.1	11.32	**516.08**
Azotobacter	126.3	26.3	70.9	23.9	11.63	**508.09**
Azospirillum	126.9	26.9	71.4	23.8	11.64	**596.08**
Azotobacter* + *Azospirillum	140.2	30.2	85.6	27.4	12.12	**669.14**
CD (P=0.05)	**10.4**	**3.6**	**5.8**	**3.0**	**0.62**	**40.36**

*FYM = Farm Yard Manure

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 Economics of production for different treatments with wheat *cv*. HD 2967.

Treatment	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Output input ratio (₹/₹)	Benefit cost ratio (₹/₹)
FYM level (t/ha)					
0	31000	87919	57919	2.83	1.87
5	32600	100651	68051	3.08	2.08
10	34200	118967	84767	3.47	2.48
N level (kg/ha)					
40	34716	89030	54314	2.56	1.64
80	35232	100260	65002	2.85	1.84
120	35748	112091	76343	3.14	2.14
Biofertilizer					
Control	34350	89534	55184	2.61	1.60
Azotobacter	34980	100094	65114	2.86	1.86
Azospirillum	35120	100062	65942	2.84	1.88
Azotobacter+Azospirillum	35750	110166	74416	3.08	2.08

*FYM = Farm Yard Manure

Fig.1

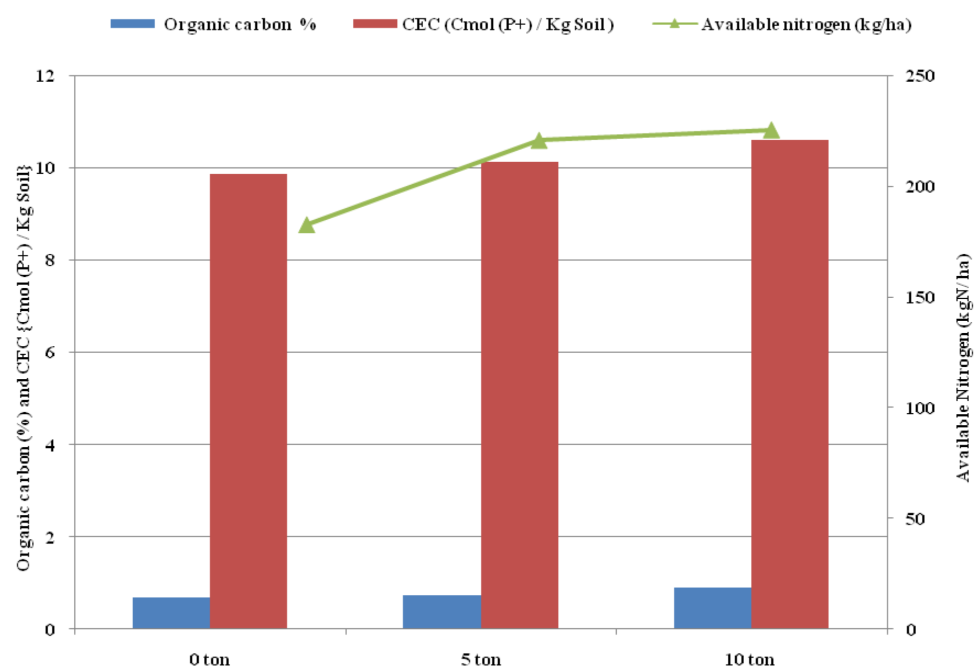

Fig.1: Organic carbon, CEC and available soil nitrogen as influenced by FYM levels.

Fig.2

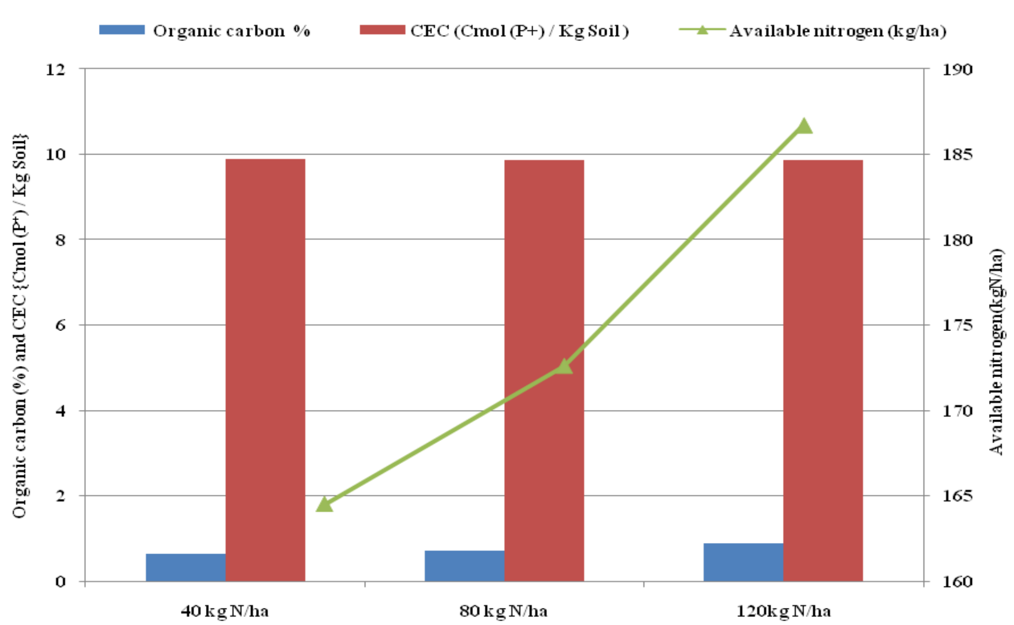

Fig.2: Organic carbon, CEC and available soil nitrogen as influenced by N levels

Fig.3

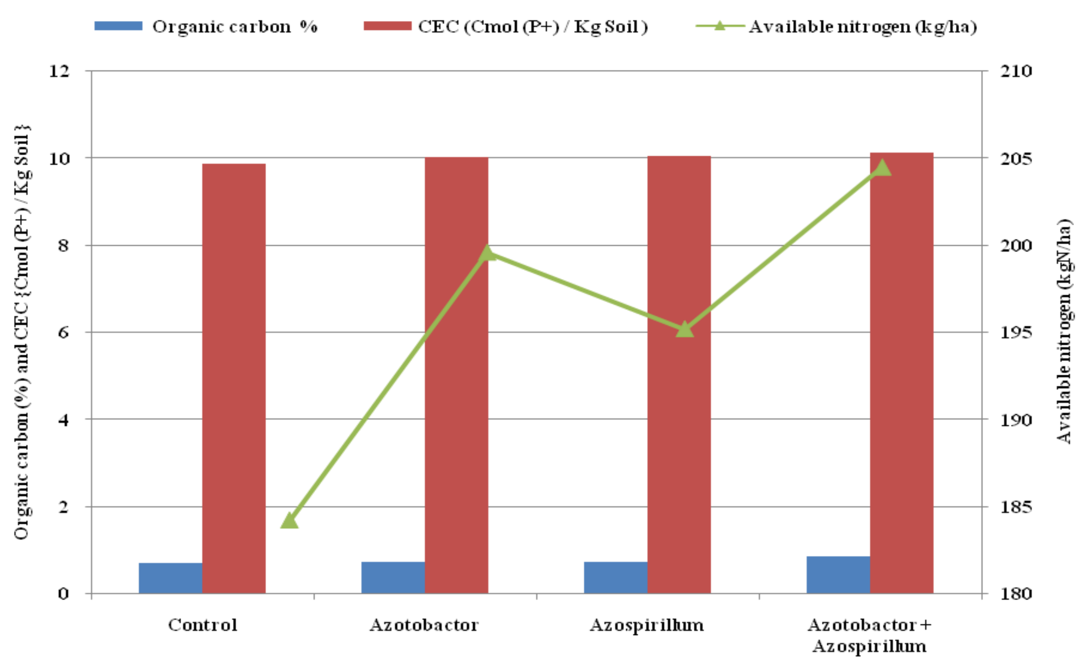

Fig.3: Organic carbon, CEC and Available soil nitrogen as influenced by biofertilizers.

Fig.4

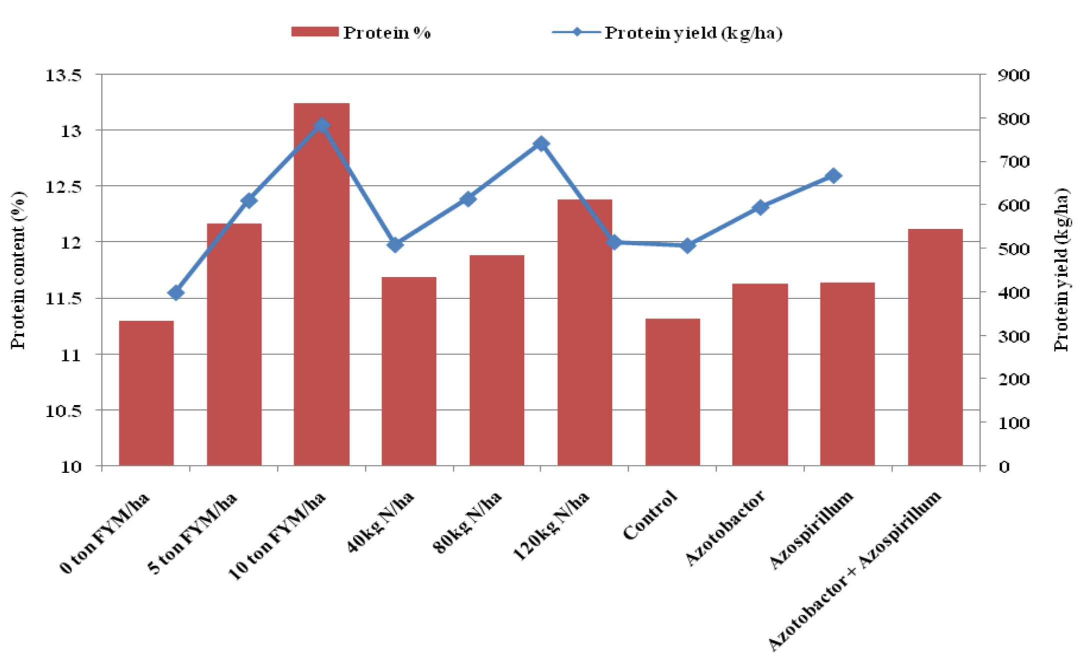

Fig.4 Protein content and Protein yield as influenced by FYM, N and biofertilizers.

Fig.5

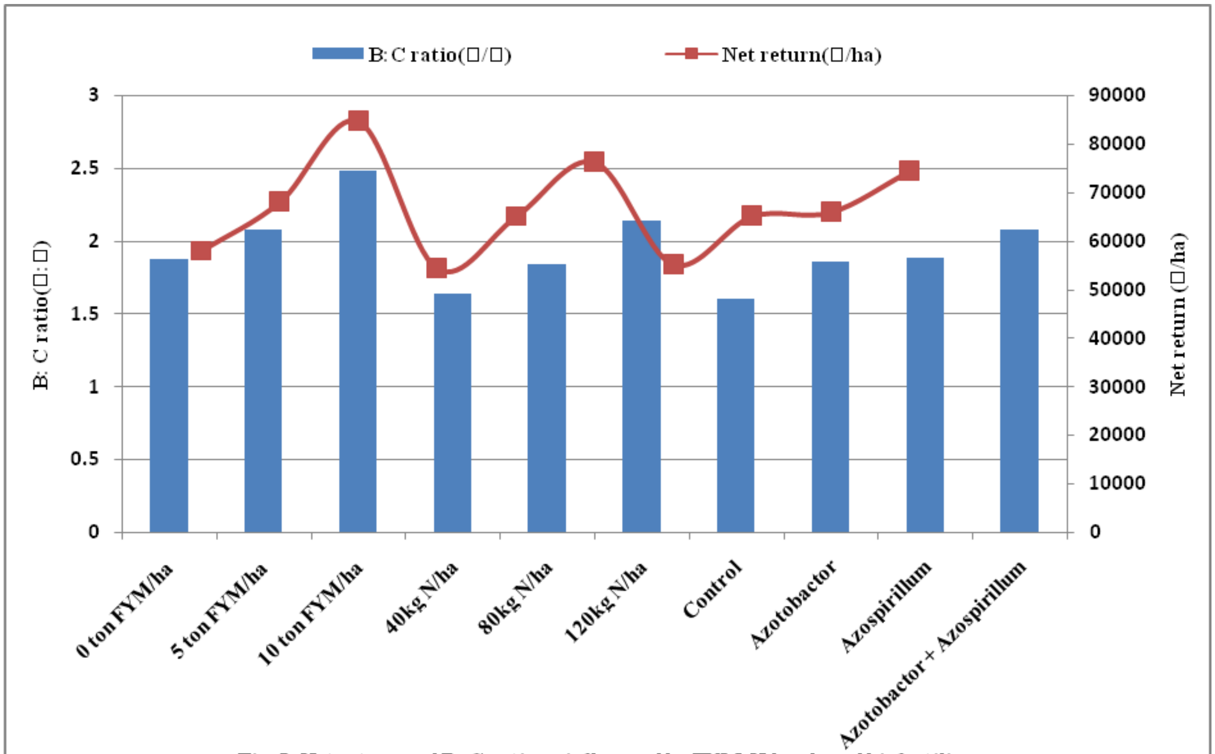

Fig. 5: Net return and B: C ratio as influenced by FYM, N levels and biofertilizers.

Higher cost of production with 10 ton FYM was due to additional cost for purchase and additional labour required for its application in field. Whereas, higher gross and net return, output: input and benefit: cost ratio might was due to relatively higher grain and straw yield obtain with 10 ton FYM level.

Similarly highest cost of production (₹ 35748/ ha), 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. 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 gross, 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 gross return (₹ 110166/ ha), 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.4). Similar results were reported by Manish Kakralia and Rajesh Singh, (2018).

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, favorably changed water holding capacity, bulk density, organic carbon, CEC and available N status in soil.

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 and improve soil environment for higher productivity.

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