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Effect of various biofertilizers applied at different nitrogen levels on growth, yield and nitrogen use efficiency of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted during rabi season of 2020-2021 at agronomy research farm of lovely professional university, phagwara. The experimental composed of 3 nitrogen levels (N0- 0% RDN, N50- 50% RDN, and N100- 100% RDN) in main plots and 4 biofertilizers i.e. BO-(no biofertilizer), BC - (Consortium), BA – (Azotobacter) and BAZ- (Azospirillum) in subplots with 12 treatment combinations in split plot design with three replications. Based on the complete analysis of experimental results it is concluded that irrespective of biofertilizers, there was a significant increase in growth parameters, yield parameters and yield, NUE and quality parameters at N50 compared to N0. There was further significant increase when N was increased to N100. All the biofertilizers irrespective of N levels, increased the growth parameters, yield parameters and yield, NUE and quality parameters significantly as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers on was non-significant but BC, BA, BAZ were produced significantly higher plant height, dry matter accumulation, crop growth rate, leaf area and leaf area index, spike length, number of grains spike^{-1}, biological yield when applied in combination with N50 which further increased significantly at N100. Different biofertilizers applied in combination with N100 resulted in higher economic returns and B:C ratio.

Keywords: Biofertilizers, plant height, yield, wheat, N use efficiency, B:C ratio

1. Introduction
Wheat is the highly important primary food of the world. Wheat is rich in carbohydrates, proteins, minerals. Wheat (*Triticum aestivum* L.) is an annual plant of Gramineae family. Wheat is an annual, self-pollinated, photo periodically long day plant. It is highly important crop providing approx. 40% among total food grain production and stands next to rice.So India persists at threat because of escalating population and modest worsening of agricultural environments due to hasty development and curbing cultivation area due to extended demand for land, water and other reserves for other sectors usage apart from agriculture. It competes well with other crucial cereals in its nutritional content. It comprises 11-12 per cent protein which is more than other cereals. It is the primary food material for more than 35% people of the world as it offers more protein and calories in the nutrition.
Biofertilizers play a very momentous role in enlightening soil fertility by fixing atmospheric nitrogen, both, in connotation with plant roots and deprived of it, solubilize inexplicable soil phosphates and releases plant growth constituents in the soil. They are in fact being indorsed to harvest the obviously available, biological system of nutrient mobilization. An integrated tactic for use of biofertilizers with chemical fertilizers is regarded as the need of hour, as biofertilizers are not replacement of fertilizers but can complement their necessity. One conceivable way of accomplishing this is to diminution dependency on use of chemical nitrogen fertilizers by garnering the atmospheric nitrogen over biological processes (Kachroo and Razdan, 2006) [1].
The goal of sustainable production can be accomplished without any change in soil health and productivity of crop by collective application of Farm Organic Manures, chemical fertilizers and

biofertilizers. Biofertilizers are the tiny organisms which are advantageous to the plant growth, quality and accountable for supreme yield production. It is apparent that biofertilizers like Azotobacter, and Azospirillum lonely or in the amalgamation have prodigious vision for increasing productivity of wheat (Kumar and Ahlawat., 2004) [2]. Utilization of biofertilizers such as biological nitrogen fixing and phosphate solubilizing micro-organisms is also earning significance since biofertilizers are cost efficient, eco-friendly, and renewable source of plant nutrient to supplementary chemical fertilizers. Above all, the task of balanced fertilizer is the application of crucial plant nutrients in right quantity and in ideal quantity for a specific soil crop ailment in relieving the yield, quality and its characteristics of wheat production is vital. In alliance with this, research on impact of biofertilizers on growth, yield and quality parameters are significantly affected (Chondie, 2015) [3].

Nitrogen and phosphorus are considered to be indispensable nutrients to upsurge the growing of plant, germination frequency, they also advance sapling emergence and guard plants from diverse stresses. But usage of synthetic chemical fertilizers is not considered as frugally and environmentally appropriate. They cause air and ground water pollution is in surface of water bodies. Conformist, chemically administered fertilizers also disrupt the soil ecology, interrupt environment, destroy soil fertility and subsequently shows destructive effects on human well-being (Suhag 2016) [4]. Therefore, the practice of chemical farming put the long-run sustainability of agriculture at hazard. There is necessity to advance and implement production system that would be productive, justifiable and smallest troublesome on the environment. Advantageous rhizosphere microorganisms can increase plant growth via numerous regulatory biochemical pathways (characterized as direct and indirect tackles) that comprises employing the plant hormonal gesticulating, avoiding pathogenic microbial straining and increasing the bioavailability of soil-borne nutrients (Bargaz *et al* 2018) [5]. A combined approach for usage of biofertilizers with chemical fertilizers is measured as the need of hour as biofertilizers are not replacement of fertilizers but can complement their obligation (Patra and Singh 2018) [6].

Wheat is a comprehensive feeder and necessitates considerable quantity of nutrients for advanced production. Nitrogen is expensive input and a foremost share of it is utilized for cereal cultivation. The cost of nitrogen fertilizers is rising day by day. Under such a condition, appropriate substitute nutrient amalgamations are to be estimated. Plants absorb maximum of their nitrogen as the ammonium (NH4+) or nitrate (NO3-) form. Nitrogen is essential for chlorophyll synthesis as a part of the chlorophyll molecule, tangled in photosynthesis and component of all amino acids and protein which are measured as answerable for quality of wheat. Application dose and time of nitrogen are very imperative for yield and quality of wheat.

Biofertilizers show a momentous character in enlightening soil fertility by setting atmospheric nitrogen both in connotation with plant roots and deprived of it, solubilize inexplicable soil phosphates and produces plant growth elements in the soil. They are in fact being encouraged to harvest the obviously available, biological system of nutrient armament. It has been professed that the soil comprises free living microscopic organisms which are capable to fix nitrogen non-symbiotically. The usage of biofertilizer injection is one of the way to reduce the nitrogen need level in wheat and it will benefit in tumbling the price of production as biofertilizer is a inexpensive basis of nitrogen. Biofertilizer is a ingredient which encompasses living microorganisms which on supplying encourages growth of plant by increasing the obtainability of nutrients. These micro-organisms assist as a feasible substitute to nitrogenous fertilizers and encompass relatively a smaller amount of price. Though, the productivity of wheat underneath late sown ailment can be amplified by the submission of appropriate fertilizer level beside with biofertilizers. *Azotobacter*, a nonsymbiotic bio-fertilizer contributes about 20-25 kg N ha^{-1} in crop like wheat, maize, cotton and other crops under fortunate conditions. *Azotobacter* is a free-living nitrogen fixing bacterium fixes yearly 60-90 kg N ha^{-1}. Bio mix is a inimitable combination of certain sp. of microbes which can solubilize lingering phosphates, iron, magnesium etc. from soil assembling them further effortlessly obtainable to plants. It excites germination and assistances to upsurge water holding capacity of soil.

The unnecessary usage of chemical fertilizers had some adversative consequence on soil health and atmosphere. Consequently, to accomplish enhanced and justifiable soil fertility and crop yield, well-adjusted and integrated submission of chemical, biological and organic fertilizers must be a key factor. Possession of these realities in view, the contemporary research work was commenced to study “Effect of various biofertilizers applied at different levels of nitrogen on growth, yield and nitrogen use efficiency of wheat (*Triticum aestivum* L.)”

2. Materials and Methods

The materials and methods utilized and followed for attaining results of experiment entitled “Effect of various biofertilizers applied at different levels of nitrogen on growth, yield and nitrogen use efficiency of wheat (*Triticum aestivum L*.)” are discussed in this chapter.

2.1 Experimental site

This study was conducted in the experimental area of agronomy, lovely professional university, phagwara. The plant sample analysis was carried out in the school of agriculture, lovely professional university, Phagwara during *rabi* season of 2020-2021. It is located in northwestern india at latitude 31022’31.81’N, altitude of 232 meter above mean sea level and longitude 75023’03.02’E.

2.2 Location and Climate

Climate of the experimental field comes under Agro ecological sub region (northern plain, hot sub humid eco region Punjab). Agro climatic zone (trans-gangetic plain region). The area comes under the semi-arid zone with annual rainfall 527.1 mm/annually. Six Agro climatic zones have been classified to characterized climatic zone distribution in Punjab and the research area is in Maheru village of Kapurthala district, which lies in northern plain zone. The minimum and maximum temperatures vary greatly during both winter and summer seasons. At the crop growth stages, the average temperature range was between 4-37^{0}C which was ideal for crop growth and development. The annual rainfall in the region is 500-750 mm, with the majority rainfall during the monsoon season (July to September). During the winter months of December, January and February there is very little rainfall.

2.3 Experimental design and treatments

The experimental design was laid in split plot design based on Split plot design (SPD) with three replicates. Treatments were randomly allotted to different plots. The lay out and experiment plan along with treatments are shown here below:

1. Total number treatment combinations = 12

2. Replications: 3
3. Design: Split Plot Design
4. Total number of plots: 36
5. Plot size: 5.0 m x 3.0 m = 15m^2
6. Row to row spacing: 22.5 cm

2.3.1 Treatments
A) Main plot treatments
i) N0 (Control)
ii) N50 (50% recommended dose of nitrogen)
iii) N100 (100% recommended dose of nitrogen)

B) Sub plot treatments
i) B0 (no biofertilizer)
ii) BC Consortium(C)
iii) BA Azotobacter(A)
iv) BAZ Azospirillum(Az)

3. Results and Discussion
3.1 Growth parameters
3.1.1 Emergence count (plants per m^2)
After 15 days of sowing plant stand was counted and data presented in table 1. Irrespective of biofertilizers, there was no significant increase in emergence count at N50 compared to N0. There no further significant increase in emergence count when N was increased to N100. All the biofertilizers irrespective of N levels, failed to increase the agronomic efficiency of N and effect of all the biofertilizers on emergence count were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on emergence count.

Table 1: Effect of biofertilizers and nitrogen levels on emergence count (m^2)

Nitrogen levels	Biofertilizers				
	BO	BC	BA	BAZ	Mean
N0	130	132	131	131	131
N50	131	132	132	132	132
N100	133	133	133	134	133
Mean	131	132	132	132	
	Nitrogen	Biofertilizers	Interaction		
LSD (0.05)	NS	NS	NS		

3.1.2 Plant height (cm)
Plant height is chief index for growth rate and yield of the crop. Plant height was recorded at different intervals of growth stages of crop is presented in table 2.

At 30 DAS irrespective of biofertilizers, there was a significant increase in plant height at N50 compared to N0. There was no further significant increase in plant height when N was increased to N100 which is statistically at par with N50. All the biofertilizers irrespective of N levels, increased the plant height significantly as compared to B0 and the differences among the biofertilizers were also significant which were BC, BA and BAZ respectively. However, the interaction between various levels of nitrogen and different biofertilizers on was non- significant.

At 60 DAS irrespective of biofertilizers, there was a significant increase in plant height at N50 compared to N0. There was further significant increase when N was increased to N100. All the biofertilizers irrespective of N levels, increased the plant height significantly as compared to B0 and the differences among the biofertilizers were also significant which were BC, BA and BAZ respectively. However, the interaction between various levels of nitrogen and different biofertilizers was significant. All the biofertilizers were produced significantly higher plant height when applied in combination with N50 which further increased significantly at N100.

At 90 DAS irrespective of biofertilizers, there was a significant increase in plant height at N50 compared to N0. There was further significant increase when N was increased to N100. All the biofertilizers irrespective of N levels, increased the plant height significantly as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant.

At maturity irrespective of biofertilizers, there was a significant increase in plant height at N50 compared to N0. There was further significant increase when N was increased to N100. All the biofertilizers irrespective of N levels, increased the plant height significantly as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was significant. However, the interaction between various levels of nitrogen and different biofertilizers was significant. All the biofertilizers were produced significantly higher plant height when applied in combination with N50 which further increased significantly at N100. Barik and Goswami (2003) observed that application of 75% recommended dose of N combined with Azospirillum or Azotobacter seed treatment showed at par results compared with 100% recommended nitrogen (100 kg/ha) regarding to plant height. Basir *et al.* (2020) [7] experimented and found that the treatment combination of [50% RDF + 10 t FYM ha^{-1} + 200 g Azotobacter 10 kg^{-1} seed] gave the best results with respect to plant height. Akhtar *et al.* (2016) [8] observed that significantly higher plant height recorded under the treatment of 75% RDF + Azotobacter + PSB.

Table 2: Effect of biofertilizers and nitrogen levels on plant height (cm)

	Biofertilizers				
Nitrogen levels	BO	BC	BA	BAZ	Mean
30 DAS					
N0	19.9	20.3	20.8	20.9	20.5
N50	21.3	21.6	21.7	22	21.7
N100	22.3	22.5	22.7	23.3	22.7
Mean	21.2	21.5	21.8	22.1	
60 DAS					
N0	35.5	36	36.7	36.8	36.2
N50	38.1	38.6	39.8	41.7	39.6
N100	42	42.9	43.8	44.9	43.4
Mean	38.5	39.2	40.1	41.1	
90 DAS					
N0	61.6	62.4	63.6	65.1	63.2
N50	66.2	67.5	69.6	70.5	68.4
N100	71	72.5	73.1	73.7	72.6
Mean	66.2	67.5	68.8	69.8	
At maturity					
N0	92	99	96	94	95
N50	99	103	105	105	103
N100	107	108	109	110	108
Mean	99	103	103	103	
		Nitrogen	Biofertilizers	Interaction	
LSD (0.05)	30 DAS	1.011	0.276	NS	
	60 DAS	0.925	0.403	1.094	
	90 DAS	1.59	0.558	NS	
	At maturity	1.545	0.998	2.129	

3.1.3 Periodical dry matter accumulation (g m.r.l^{-1})

Dry matter accumulation is an important growth parameter to observe metabolic growth rate of plants. Dry matter accumulation of meter row length at various growth stages was determined and presented in table 3.

At 30 DAS irrespective of biofertilizers, there was a significant increase in dry matter accumulation at N50 compared to N0. There was further significant increase in dry matter accumulation when N was increased to N100. All the biofertilizers irrespective of N levels, increased the dry matter accumulation significantly as compared to B0 and but the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers on dry matter accumulation was non-significant.

At 60 DAS irrespective of biofertilizers, there was a significant increase in dry matter accumulation at N50 compared to N0. There was further significant increase in dry matter accumulation when N was increased to N100. All the biofertilizers irrespective of N levels, effect on dry matter accumulation were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on dry matter accumulation.

At 90 DAS irrespective of biofertilizers, there was a significant increase in dry matter accumulation at N50 compared to N0. There was further significant increase in dry matter accumulation when N was increased to N100. All the biofertilizers irrespective of N levels, increased the dry matter accumulation significantly as compared to B0 and but the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers on dry matter accumulation was non-significant.

At maturity irrespective of biofertilizers, there was a significant increase in dry matter accumulation at N50 compared to N0. There was further significant increase when N was increased to N100. All the biofertilizers irrespective of N levels, increased the dry matter accumulation significantly as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was significant. All the biofertilizers were produced significantly higher plant dry matter accumulation when applied in combination with N50 which further increased significantly at N100. Nagwa *et al* (2017) [9] found that he collective treatment of bio-fertilizers and mineral nitrogen was significantly increased dry matter accumulation. Kalia and Mankotia (2005) [11] observed that with Azotobacter and 100% recommended dose of nitrogen significantly increased the dry matter accumulation. Singh *et al*. (2013) [10] observed that seed treatment with Azotobacter and Azospirillum improved significantly plant height, dry matter of wheat than no inoculation.

Table 3: Effect of biofertilizers and nitrogen levels on dry matter accumulation (g m.r.l^{-1})

Nitrogen levels	Biofertilizers				
	BO	**BC**	**BA**	**BAZ**	**Mean**
30 DAS					
N0	3.46	4.17	3.86	4.09	3.89
N50	4.72	5.58	5.66	5.74	5.43
N100	7.55	8.34	8.26	8.42	8.14
Mean	5.24	6.03	5.93	6.08	
60 DAS					
N0	21.2	23.6	26	26	24.2
N50	33	33.8	34.6	35.4	34.2
N100	44.8	46.4	44.8	45.6	45.4
Mean	33	34.6	35.1	35.7	
90 DAS					
N0	122	125	125	127	125
N50	144	151	150	150	149
N100	170	173	172	173	172
Mean	145	150	149	150	
At maturity					
N0	175	177	177	177	177
N50	219	223	223	223	222
N100	261	265	265	265	264
Mean	218	222	222	222	
		Nitrogen	**Biofertilizers**	**Interaction**	
LSD (0.05)	30 DAS	0.945	0.292	NS	
	60 DAS	2.688	NS	NS	
	90 DAS	0.966	1.028	NS	
	At maturity	0.467	0.493	0.868	

3.1.4 Number of tillers (m.r.l^{-1})

Data relating to no of tillers counted per metre row length at different intervals was observed and presented in table 4.

At 30 DAS irrespective of biofertilizers, there was a significant increase in number of tillers at N50 compared to N0. There was further significant increase in number of tillers when N was increased to N100. Effect of all the biofertilizers irrespective of N levels, on the number of tillers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on number of tillers.

At 60 DAS irrespective of biofertilizers, there was a significant increase in number of tillers at N50 compared to N0. There was further significant increase in number of tillers when N was increased to N100. Effect of all the biofertilizers irrespective of N levels, on the number of tillers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on number of tillers.

At 90 DAS irrespective of biofertilizers, there was a significant increase in number of tillers at N50 compared to N0. There was further significant increase in number of tillers when N was increased to N100. Effect of all the biofertilizers irrespective of N levels, significantly increased number of tillers but the differences between biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on number of tillers.

At maturity irrespective of biofertilizers, there was a significant increase in number of tillers at N50 compared to N0. There was further significant increase in number of tillers when N was increased to N100. Effect of all the biofertilizers irrespective of N levels, significantly increased number of tillers but the differences between biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on number of tillers. Basir *et al.* (2020) [7] experimented and observed that the treatment combination of [50% RDF + 10 t FYM ha^{-1} + 200 g Azotobacter 10 kg^{-1} seed] gave the best results with respect to number of tillers (104.81) over control.

Table 4: Effect of biofertilizers and nitrogen levels on number of tillers ($m.r.l^{-1}$)

Nitrogen levels	Biofertilizers				
	BO	BC	BA	BAZ	Mean
30 DAS					
N0	26	27.3	27.3	26.3	26.8
N50	32.3	31	31	33.3	31.9
N100	34.7	35	35	35.3	35
Mean	31	31.1	31.1	31.7	
60 DAS					
N0	52	53.3	53	53.3	52.9
N50	66.3	67	66.7	66.7	66.7
N100	71.3	73.3	72.7	73	72.6
Mean	63.2	64.6	64.1	64.3	
90 DAS					
N0	71.3	73	72	72.3	72.2
N50	91.7	94.3	92.3	93.3	92.9
N100	111	115	114	115	114
Mean	91.2	94.2	92.8	93.4	
At maturity					
N0	72.3	74.3	73.3	74.7	73.7
N50	93	95.3	93.7	94.7	94.2
N100	112	117	115	117	115
Mean	92.6	95.6	94.1	95.3	
		Nitrogen	**Biofertilizers**	**Interaction**	
LSD (0.05)	30 DAS	3.365	NS	NS	
	60 DAS	1.439	NS	NS	
	90 DAS	2.423	1.688	NS	
	At maturity	2.838	2.04	NS	

3.1.5 Chlorophyll index

chlorophyll index by SPAD meter at different intervals was determined and presented in table 5. At 30 DAS irrespective of biofertilizers, there was a significant increase in chlorophyll index at N50 compared to N0. There was further significant increase in chlorophyll index when N was increased to N100. BA and BAZ irrespective of N levels, increased the chlorophyll index significantly as compared to BO. BC failed to increase chlorophyll index but the differences among the biofertilizers was non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on chlorophyll index.

At 60 DAS irrespective of biofertilizers, there was a significant increase in height at N50 compared to N0. There was no further significant increase in plant height when N was increased to N100 which is statistically at par with N50. Effect of all the biofertilizers on chlorophyll index irrespective of nitrogen levels was non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant.

At 90 DAS irrespective of biofertilizers, there was a significant increase in height at N50 compared to N0. There was no further significant increase in plant height when N was increased to N100 which is statistically at par with N50. Effect of all the biofertilizers on chlorophyll index irrespective of nitrogen levels was non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant.

Table 5: Effect of biofertilizers and nitrogen levels on chlorophyll index

Nitrogen levels	Biofertilizers				
	BO	BC	BA	BAZ	Mean
30 DAS					
N0	24	24.4	24.9	25.2	24.6
N50	30.5	30.6	30.7	31	30.7
N100	34.7	35.9	35.9	36	35.6
Mean	29.8	30.3	30.5	30.7	
60 DAS					
N0	30.5	30.6	30.7	31.3	30.8
N50	35	35.9	35.9	36	35.7
N100	43.1	43.3	43.5	43.7	43.4
Mean	36.2	36.6	36.7	37	
90 DAS					
N0	41.8	41.9	41.9	42.8	42.1
N50	46.3	46.1	46.4	46.6	46.4
N100	51.1	52.1	53.4	53.5	52.5
Mean	46.4	46.7	47.2	47.6	
		Nitrogen	**Biofertilizers**	**Interaction**	
LSD (0.05)	30 DAS	0.616	0.645	NS	
	60 DAS	0.596	NS	NS	
	90 DAS	1.246	NS	NS	

3.2 Yield parameters

3.2.1 No of effective tillers ($m.r.l^{-1}$)

Effective tillers is a significant parameter which influences grain yield of wheat. Tillers which are produced complete productive spikes found per meter row length and data regarding to this parameter presented in table 6.

At maturity irrespective of biofertilizers, there was a significant increase in number of effective tillers at N50 compared to N0. There was further significant increase in number of effective tillers when N was increased to N100. Effect of all the biofertilizers irrespective of N levels, on the number of effective tillers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on number of effective tillers. Kalia and Mankotia (2005) [11] observed that with Azotobacter and 100% recommended dose of nitrogen significantly increased the number of effective tillers/m^2 in wheat over no biofertilizer.

Table 6: Effect of biofertilizers and nitrogen levels on number of effective tillers (m.r.l^{-1})

Nitrogen levels	Biofertilizers				
	B0	BC	BA	BAZ	Mean
N0	61.3	63.3	62.7	63.0	62.6
N50	84.3	85.3	84.0	86.7	85.1
N100	103	105	104	104	104
Mean	82.8	84.7	83.6	84.7	
	Nitrogen	Biofertilizers	Interaction		
LSD (0.05)	2.316	NS	NS		

3.2.2 Spike length (cm)

Spike length is a significant character which decides number of grains and spikelets per spike. Data regarding to the spike length observed and presented in table 7. Irrespective of biofertilizers, there was a significant increase in spike length at N50 compared to N0. There was further significant increase in spike length when N was increased to N100. All the biofertilizers irrespective of N levels, increased the spike length significantly as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was significant. B0 produced significantly higher spike length when applied in combination with N50 and there is no further significant increase at N100. BC produced significantly higher spike length when applied in combination with N100 compared to N0 and N50. BA and BAZ produced significantly higher spike length when applied in combination with N50 which further significantly increased at N100. Akhtar *et al.* (2016) [8] conducted an experiment and observed that significantly higher length of spike recorded significantly higher under the treatment of 75% RDF + Azotobacter + PSB over control. Nehal and naggar (2018) concluded that combined application Azotobacter with 120 kg N ha^{-1} resulted in significant improvement of spike length of wheat in comparison to control and 120 kg N ha^{-1}. Mane *et al.* (2014) [12] reported that the application of 125% RDF (80:40:40 kg NPK ha) Azotobacter + PSB in wheat resulted significantly higher spike length than sole RDF and no bofertilizer.

3.2.3 Spike weight (gm)

Spike weight is an important yield contributing parameter. Data related to spike weight presented in table 7. Irrespective of biofertilizers, there was a significant increase in spike weight at N50 compared to N0. There was further significant increase in spike weight when N was increased to N100. Effect of biofertilizers irrespective of N levels, on the weight was significant as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant. Mane *et al.* (2014) [12] reported that the application of 125% RDF (80:40:40 kg NPK ha) Azotobacter + PSB in wheat significantly higher weight of grains per spike of wheat than sole RDF and no bofertilizer. Nagwa *et al.* (2017) [9] combination of 100% mineral N and mixture of Azospirillum sp. and Azotobacter sp. occasioned in the significant increase in weight of spike compared to 100% (NRD) treatment.

3.2.4 Number of spikelets spike^{-1}

Data regarding to number of spikelets per spike presented in following table 7. Irrespective of biofertilizers, there was a significant increase in spikelets per spike at N50 compared to N0. There was further significant increase in spikelets per spike when N was increased to N100. Effect of biofertilizers irrespective of N levels, on the spikelets per spike were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant. Esmailpour *et al.* (2013) [13] reported that combined application of chemical nitrogen, Azotobacter and livestock manure enhanced significantly number of spikelets spike^{-1} in wheat over sole application nitrogen.

3.2.5 Number of grains spike^{-1}

Number of grains per spike is one of the important yield contributing and deciding parameter of economical yield. Data observed related to number of grains per spike presented in table 7. Irrespective of biofertilizers, there was a significant increase in number grain spike^{-1} at N50 compared to N0. There was further significant increase in grain per spike^{-1} when N was increased to N100. Effect of biofertilizers BAZ and BA irrespective of N levels, on the spike length was significant compared to BO but the BC failed to increase grains spike^{-1}. However, the interaction between various levels of nitrogen and different biofertilizers was significant. B0 and BC produced significantly higher number of grains spike^{-1} when applied in combination with N100 compared to N0 and N50. BA and BAZ produced significantly higher number of grains spike^{-1} when applied in combination with N50 which further significantly increased at N100. Heidaryan and Feilinezhad (2015) [14] concluded that suppliers of biological nitrogen fixation and phosphorous solubilizers had significant increase on number grains per spike which eventually followed in considerable escalation in grain yield by combined application over individual application.

Table 7: Effect of biofertilizers and nitrogen levels on spike parameters

Nitrogen levels	Biofertilizers				
	BO	BC	BA	BAZ	Mean
Spike length(cm)					
N0	9.37	9.46	9.46	9.49	9.44
N50	9.97	9.80	9.97	10	9.94
N100	10.2	11.0	11.1	10.9	10.8
Mean	9.84	10.1	10.2	10.1	
Spike weight (g)					
N0	2.87	2.85	3.33	3.41	3.12
N50	3.67	3.72	3.89	3.89	3.79
N100	4.01	4.27	4.36	4.27	4.23
Mean	3.52	3.62	3.86	3.86	
Number of spikelets per spike^{-1}					
N0	14.7	15.0	15.3	15.3	15.1
N50	17.3	17.3	17.7	17.7	17.5
N100	18.7	19.0	19.3	19.7	19.2
Mean	16.9	17.1	17.4	17.6	
Number of grains spike^{-1}					
N0	39	40.2	41.1	40.1	40.1
N50	40.3	41.9	44.8	50.2	44.3
N100	51.9	54	56	55.5	54.4
Mean	44.2	45	47.3	48.6	
			Nitrogen	Biofertilizers	Interaction
LSD (0.05)	Spike length(cm)		0.314	0.209	0.439
	Spike weight(g)		0.101	0.169	NS
	No of spikelets spike^{-1}		0.475	NS	NS
	No of grains per spike^{-1}		0.734	1.317	2.1

3.2.6 Test weight

Test weight is weight of 1000 grains which is important parameter in influencing the grain yield. Data related to 1000 grain weight mentioned in table 8. Irrespective of biofertilizers, there was a significant increase in test weight at N50 compared to N0. There was further significant increase in biological yield when N was increased to N100. Biofertilizers BAZ and BA irrespective of N levels, increased the plant height significantly as compared to B0 but the BC failed to increase the test weight and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on test weight. Nehal and naggar (2018) concluded that combined application Azotobacter with 120 kg N ha^{-1} resulted in significant improvement of 1000-grain weight of wheat in comparison to control and 120 kg N ha^{-1}. Hassanein *et al.* (2018) observed that treatment combinations of Sohag-4 cultivar+ 90 kg N + Azotobacter and Sohag- 4 cultivar+ 90 kg N + Yeast for grain yield (g/m^2) were produced significantly higher test weight (g) compared sole application of biofertilizer and nitrogen.

Table 8: Effect of biofertilizers and nitrogen levels on 1000 grain weight (g)

Nitrogen levels	Biofertilizers				
	BO	**BC**	**BA**	**BAZ**	**Mean**
N0	35.3	35.7	35.7	35.9	35.7
N50	37.9	38.2	38.8	38.8	38.4
N100	43.6	43.6	43.9	44.7	44.0
Mean	38.9	39.2	39.5	39.8	
	Nitrogen	**Biofertilizers**	**Interaction**		
LSD (0.05)	0.417	0.577	NS		

3.3 Yield

3.3.1 Biological yield (kg ha^{-1})

Biological yield is complete biomass resulted in whole life cycle of plants. Biological yield obtained under different treatments. Data of biological yield presented in table 9. Irrespective of biofertilizers, there was a significant increase in biological yield at N50 compared to N0. There was further significant increase in biological yield when N was increased to N100. All the biofertilizers irrespective of N levels, increased the biological yield significantly as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was significant. All the biofertilizers were produced significantly higher biological yield when applied in combination with N50 which further significantly increased at N100. Singh and Sharma (2016) [15] reported that supplement of 75% NPK + 1t ha vermicompost + Azospirillum 100% NPK (RDF- recommended dose of fertilizer i.e.,120: 60: 40 kg NPK ha observed significantly elevated yield in wheat in terms of biological yield and grain yield (q ha'), compared to 100% NPK (RDF-recommended dose of fertilizer i.e.,120: 60: 40 kg NPK ha^{-1}.

3.3.2 Grain yield (kg ha^{-1})

Economical yield is final total produced grain weight which is the result of cumulative effect of growth parameters like plant height, dry matter accumulation, crop growth rate, number of tillers, leaf area, chlorophyll index and yield parameters like grain per spike, effective tillers, test weight, spike length. Data of grain yield presented in table 9.

Irrespective of biofertilizers, there was a significant increase in grain yield at N50 compared to N0. There was further significant increase in grain yield when N was increased to N100. All the biofertilizers irrespective of N levels, increased the grain yield significantly as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on grain yield. Singh *et al.* (2007) [16] observed that the combined application of inorganic fertilizer, biofertilizer and organics improved the yield of wheat. Highest yield characteristics were observed in 150 kg N ha^{-1} followed by 50 kg N ha^{-1} + Azospirillum + FYM 5 t ha^{-1}. Further economical yield and straw yields of wheat increased significantly at higher levels of N and collaborative application of organic and bio-fertilizers. Yadav *et al.* (2011) [17] reported that combined use of Azotobacter + Azospirillum with 75% RDF resulted in significantly enhanced yield attributes, grain yield, followed by Azotobacter and Azospirillum as alone compared to control in wheat. Singh *et al.* (2018) [18] found that application of 100% NPK + FYM + PSB + Azotobacter + Zn + Fe + Mn noticed significantly higher grain yield (58.40 q ha) and straw yield (83.9 q ha) of wheat. Verma *et al.* (2015) [19] experimented and revealed that the treatment composed of RDF + vermicompost 5.0 t/ha + *Azotobacter* and PSB as seed treatment resulted in significantly higher grain yield (56.70 q/ha) of wheat compared to control (RDF).

3.3.3 Straw yield (kg ha^{-1}):

Straw yield is obtained by extracting grain yield from biological yield which resulted by growth parameters like plant height, dry matter accumulation and leaf area etc. Data related to straw yield mentioned in table 9. Irrespective of biofertilizers, there was a significant increase in straw yield at N50 compared to N0. There was further significant increase in straw yield when N was increased to N100. All the biofertilizers irrespective of N levels, failed increase the straw yield and the effect of all the biofertilizers on straw yield were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on straw yield. Singh *et al.* (2018) [18] found that application of 100% NPK + FYM + PSB + Azotobacter + Zn + Fe + Mn noticed significantly higher grain yield (58.40 q ha) and straw yield (83.9 q ha) of wheat. weight of seeds significantly and 27% surge in yield of wheat crop upon control. Singh *et al.* (2013) [20] found that seed treatment with Azotobacter and Azospirillum significantly improved yield attributes and yield of wheat than no inoculation. Application of 120 kg/N along with above biofertilizers enhanced the yield of wheat.

3.3.4 Harvest index

Harvest index is the proportionality of grain yield to the biological yield multiplied by 100. Data of harvest index was determined and presented in table 9. Irrespective of biofertilizers, there was a significant increase in harvest index at N50 compared to N0. There was further significant increase in harvest index when N was increased to N100. All the biofertilizers irrespective of N levels, failed increase the harvest index and the effect of all the biofertilizers on harvest index were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on harvest index. Esmailpour *et al.* (2013) [10] reported that combined application of chemical nitrogen, Azotobacter and livestock manure significantly enhanced harvest index in wheat over sole application nitrogen. Nehal and naggar (2018) concluded that combined application Azotobacter with 120 kg N ha^{-1} resulted in significant improvement of harvest index of wheat in comparison to control and 120 kg N ha^{-1}.

Table 9: Effect of biofertilizers and nitrogen levels on yield and harvest index

	Biofertilizers				
Nitrogen levels	**BO**	**BC**	**BA**	**BAZ**	**Mean**
Biological yield (kg ha^{-1})					
N0	8,750.00	8,866.67	8,853.33	8,856.67	8,831.67
N50	10,966.67	11,146.67	11,136.67	11,156.67	11,101.67
N100	13,040.00	13,260.00	13,240.00	13,256.67	13,199.17
Mean	10,918.89	11,091.11	11,076.67	11,090.00	
Grain yield (kg ha^{-1})					
N0	3,613.33	3,646.67	3,660.00	3,653.33	3,643.33
N50	4,843.33	4,933.33	4,906.67	4,926.67	4,902.50
N100	6,043.33	6,193.33	6,210.00	6,256.67	6,175.83
Mean	4,833.33	4,924.44	4,925.56	4,945.56	
Straw yield (kg ha^{-1})					
N0	5,136.67	5,220.00	5,193.33	5,203.33	5,188.33
N50	6,123.33	6,213.33	6,230.00	6,230.00	6,199.17
N100	6,996.67	7,066.67	7,030.00	7,000.00	7,023.33
Mean	6,085.56	6,166.67	6,151.11	6,144.44	
Harvest index					
N0	39	40.2	41.1	40.1	40.1
N50	40.3	41.9	44.8	50.2	44.3
N100	51.9	54	56	55.5	54.4
Mean	44.2	45	47.3	48.6	
			Nitrogen	**Biofertilizers**	**Interaction**
LSD (0.05)	Biological yield (kg ha^{-1})		17.778	25.318	41.709
	Grain yield (kg ha^{-1})		75.562	66.676	NS
	Straw yield (kg ha^{-1})		89.354	NS	NS
	Harvest index		0.72	NS	NS

4. Quality analysis

4.1 Chemical analysis of plant

4.1.1 N content (%) in grain

The data pertaining to N content in grain was determined and presented in table 10. Irrespective of biofertilizers, there was a significant increase in N content in grain at N50 compared to N0. There was further significant increase in N content in grain when N was increased to N100. All the biofertilizers irrespective of N levels, increased the N content in grain significantly as compared to B0 and the differences among the biofertilizers were non- significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on N content in grain. Singh *et al.* (2008) [21] observed that the significantly higher N and P absorption by wheat with the application of FYM @ 7.5 t per ha + 50% RDF + biofertilizer (PSB + Azotobacter) followed by 100% RDF and FYM @ 15 t ha[1] being significantly higher than control. Singh and Sharma (2016) [15] reported that application of 100% NPK (RDF suggested portion of manure i.e 120:60:40 kg NPK ha recorded significantly higher estimation of supplement take-up and nitrogen content in wheat grain which was at statistically at par with the 75% NPK +1 t ha[1] vermicompost + Azospirillum.

4.1.2 N content (%) in straw

Data related to N content in straw was determined and presented in table 10. Irrespective of biofertilizers, there was a significant increase in N content in straw at N50 compared to N0. There was further significant increase in N content in straw when N was increased to N100. All the biofertilizers irrespective of N levels, failed to increase the N content in straw and effect of all the biofertilizers on N content in straw were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on N content in straw. Kader *et al.* (2002) [22] concluded that the significant N take-up (23.2 mg plant) was recorded with the treatment having 168 kg N ha' + cow dung + Azotobacter compared with the control (11.03 mg plant) in wheat. Singh *et al.* (2008) [21] observed that the significantly higher N and P absorption by wheat with the application of FYM @ 7.5 t per ha + 50% RDF + biofertilizer (PSB + Azotobacter) followed by 100% RDF and FYM @ 15 t ha[1] being significantly higher than control.

Table 10: Effect of biofertilizers and N levels on nitrogen content (%)

Nitrogen levels	Biofertilizers				
	BO	**BC**	**BA**	**BAZ**	**Mean**
N content (%) in grain					
N0	1.243	1.273	1.273	1.28	1.268
N50	1.357	1.38	1.38	1.403	1.38
N100	1.627	1.647	1.643	1.64	1.639
Mean	1.409	1.433	1.432	1.441	
N content (%) in straw					
N0	0.237	0.243	0.24	0.233	0.238
N50	0.347	0.337	0.333	0.347	0.341
N100	0.433	0.437	0.46	0.467	0.449
Mean	0.339	0.339	0.344	0.349	
			Nitrogen	**Biofertilizers**	**Interaction**
LSD (0.05)	N content (%) in grain		0.019	0.018	NS
	N content (%) in straw		0.005	NS	NS

4.1.3 N uptake by grain (kg ha^{-1})

Data regarding to the N uptake by grain was determined and presented in table 11. Irrespective of biofertilizers, there was a significant increase in N uptake by grain at N50 compared to N0. There was further significant increase in N uptake by grain when N was increased to N100. All the biofertilizers irrespective of N levels, increased the N uptake by grain significantly as compared to B0 and the differences among the biofertilizers were non- significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on N uptake by grain. Patra and Singh (2016) [6] Priming with biofertilizer inoculations significantly improved nutrient uptake of wheat. Nutrient uptake was highest at bio mix treated plot than others. The nutrient uptake showed an increase with increase in nitrogen dose up to 150 kg per hectare. Agrawal *et al.* (2004) [23] detailed that at 80 DAS, about 72.03% increase in intensity in nitrogen absorption by wheat upon the control was noticed because of Azotobacter inoculation and it was at average with the supplement of 20 kg N ha unaccompanied. Azotobacter alone and 20 kg N per ha were statistically at par in influencing the nitrogen content in straw as well as in grain.

4.1.4 N uptake by straw (kg ha^{-1})

Data regarding to the nitrogen uptake by straw was determined and presented in table 11. Irrespective of biofertilizers, there was a significant increase in nitrogen uptake by grain at N50 compared to N0. There was further significant increase in N uptake by straw when N was increased to N100. All the biofertilizers irrespective of N levels, failed to increase the N uptake by straw and effect of all the biofertilizers on N uptake by straw were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on N uptake by straw. Kader *et al.* (2002) [22] concluded that the significant N take-up (23.2 mg plant) was recorded with the treatment having 168 kg N ha' + cow dung + Azotobacter compared with the control (11.03 mg plant) in wheat. Agrawal *et al.* (2004) [23] detailed that at 80 DAS, about 72.03% increase in intensity in nitrogen absorption by wheat upon the control was noticed because of Azotobacter inoculation. Azotobacter alone and 20 kg N per ha were statistically at par in influencing the nitrogen content in straw as well as in grain.

Table 11: Effect of biofertilizers and N levels on N uptake by grain and straw (kg ha^{-1})

Nitrogen levels	Biofertilizers				
	BO	BC	BA	BAZ	Mean
N uptake by grain kg/ha					
N0	44.9	46.4	46.6	46.8	46.2
N50	65.7	68.1	67.7	69.1	67.7
N100	98.3	102	102	103	101
Mean	69.6	72.2	72.1	72.8	
N uptake by straw kg/ha					
N0	12.2	12.7	12.5	12.1	12.4
N50	21.2	20.9	20.8	21.6	21.1
N100	30.3	30.9	32.3	32.7	31.5
Mean	21.2	21.5	21.9	22.1	
			Nitrogen	Biofertilizers	Interaction
LSD (0.05)	N uptake by grain		1.509	1.115	NS
	N uptake by straw		0.482	NS	NS

N use efficiency

- **Recovery efficiency of N:** Data regarding to the recovery efficiency of N was determined and presented in table 12. Irrespective of biofertilizers, there was a significant increase in recovery efficiency of N at N50 compared to N0. There was further significant increase in recovery efficiency of N when N was increased to N100. All the biofertilizers irrespective of N levels, increased the recovery efficiency of N significantly as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on recovery efficiency of N. Gupta *et al.* (2017) [24] reported that seed treatment with biofertilizers Rhizobacteria and Azotobacter significantly enhanced N-use efficiency, apparent N recovery of wheat. Nitrogen application 120 kg/ha improved N-use efficiency and apparent N recovery in Wheat.
- **Agronomic efficiency of N:** Data regarding to the agronomic efficiency of N was determined and presented in table 12. Irrespective of biofertilizers, there was a significant increase in agronomic efficiency of N at N50 compared to N0. There was further significant increase in agronomic efficiency of N when N was increased to N100. All the biofertilizers irrespective of N levels, failed to increase the agronomic efficiency of N and effect of all the biofertilizers on agronomic efficiency of N were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on agronomic efficiency N. Kachroo and Razdan (2006) [1] reported that combined inoculation of Azotobacter+ Azospirillum significantly enhanced the nitrogen use efficiency (NUE) of wheat. Highest NUE noticed at 80 kg N/ha and further NUE is decreased by increase in N level.

Table 12: Effect of biofertilizers and nitrogen levels on nitrogen use efficiency

Nitrogen levels	Biofertilizers				
	BO	BC	BA	BAZ	Mean
Recovery efficiency of nitrogen					
N0	-	-	-	-	-
N50	49.7	49.8	49.0	53.1	50.4
N100	59.6	61.4	62.7	63.6	61.9
Mean	36.4	37.1	37.2	38.9	
Agronomic efficiency of nitrogen					
N0	-	-	-	-	-
N50	20.5	21.4	20.8	21.2	20.9
N100	20.2	21.2	21.3	21.7	21.1
Mean	13.6	14.2	14.0	14.3	
			Nitrogen	Biofertilizers	Interaction
LSD (0.05)	Recovery efficiency of nitrogen		1.382	1.551	NS
	Agronomic efficiency of nitrogen		0.802	NS	NS

4.1.5 Protein content (%)

Protein content is qualitative analysis of wheat grain and data pertaining to protein content was determined and presented in table 13. Irrespective of biofertilizers, there was a significant increase in protein content at N50 compared to N0. There was further significant increase in protein content when N was increased to N100. All the biofertilizers irrespective of N levels, increased the protein content significantly as compared to B0 and the differences among the biofertilizers were non-significant. However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on protein content. Bahrani *et al.* (2010) [25] stated that collaborative effect of Azotobacter + Mycorrhiza with nitrogen resources significantly enhanced grain protein of wheat by 13% than control. concluded that the crude protein content of wheat significantly enhanced, and total carbohydrate content declined drastically in seed with the application of nitrogen + Azotobacter in all the cultivars of wheat over no inoculation.

4.1.6 Protein yield (kg ha^{1})

Data of protein yield was calculated and presented in table 13. Irrespective of biofertilizers, there was a significant increase in protein yield at N50 compared to N0. There was further significant increase in protein yield when N was increased to N100. All the biofertilizers irrespective of N levels, increased the protein yield significantly as compared to B0 and the differences among the biofertilizers were non-significant.

However, the interaction between various levels of nitrogen and different biofertilizers was non-significant on protein yield. Akhtar *et al.* (2016) [8] reported that significantly higher values of quality parameters *viz*., protein content and protein yield of wheat were recorded significantly higher under the treatment RDF (120-60-60 kg N-P2O5- K2O per ha) + ZnSO4 @ 25 kg per ha (P from DAP) statistically par results are observed under treatment of 75% RDF + Azotobacter + PSB over control.

Table 13: Effect of biofertilizers and nitrogen levels on protein content (%) and protein yield (kg ha^{-1})

Nitrogen levels	Biofertilizers				
	BO	BC	BA	BAZ	Mean
Protein content (%)					
N0	7.77	7.96	7.96	8	7.92
N50	8.48	8.63	8.63	8.77	8.63
N100	10.2	10.3	10.3	10.3	10.2
Mean	8.81	8.96	8.95	9.01	
Protein yield (kg ha^{-1})					
N0	281	290	291	292	289
N50	411	425	423	432	423
N100	614	637	638	641	633
Mean	435	451	451	455	
			Nitrogen	Biofertilizers	Interaction
LSD (0.05)	Protein content (%)		0.121	0.112	NS
	Protein yield (kg ha^{-1})		9.644	7.106	NS

5. Economic analysis

Economic analysis of experimental treatments resulted disparity in cost of cultivation per hectare due to diverse nitrogen levels and biofertilizers utilization. The data
regarding to economic analysis of cost of cultivation, gross returns, net returns and B:C of all treatments was calculated and enlisted in table 14, 15 and 16.

5.1 Cost of cultivation: The cost of production was less in NO + BO plots as nitrogen sources and biofertilizers were not applied and more cost of cultivation was in N50 + biofertilizers and N100 + biofertilizers combinations as in these treatments nitrogen sources and biofertilizers were recommended for soil application and seed treatment so, it results in higher cost of the production than control plots.

5.2 Higher gross returns: Higher gross returns (130569, 129677 and 129385 Rs ha^1) was noticed in N100 + BAZ, N100 + BA and N100 + BC. Higher net returns was achieved (67889, 66947 and 66930 Rs ha^1) in N100 + BAZ, N100 + BA and N100 + BC. Highest benefit cost ratio (2.08, 2.07 and 2.07) was found in N100 + BAZ, N100 + BA and N100 + BC. Different biofertilizers applied in combination with N100 resulted in better economic returns. Complete details of the total cost and returns and B:C ratio were presented in table 4.17, 4.18 and 4.19. Verma *et al.* (2015) [19] experimented and observed that the higher gross income (Rs. 87443.00) and net income (Rs. 37000.00) of wheat was obtained in treatment of RDF + vermicompost 5.0 t/ha^{-1} + *Azotobacter* and PSB as seed treatment and sprayed at 1st and 2nd irrigation compared to RDF treatment (control). Yadav *et al.*, (2014) [17] reported that integrated use of 40 kg N ha^{-1} + 5t ha^{-1} FYM + 5 kg ha^{-1} biofertilizer (Azotobacter) produced maximum grain yield (36.29 q ha^{-1}) in wheat and gained highest net income (Rs. 24641 ha) and it was at par with integration of 40 kg N ha^{-1} +5 t ha FYM + 5 kg ha^{-1} Azospirillum (35.66 q ha grain yield and Rs. 23864 ha^{-1} net income) tracked by application of 120 kg N ha^{-1} (34.89 q ha^{-1} grain yield and Rs. 23173 ha^{-1} net income).

Table 14: List of common cost of cultivation

SL No	Particulars	Price (Rs)	Inputs	Total cost (Rs/ha)
1	Seeds	3000/q	1 q	3000
2	**Labour charges**			
	Sowing + layout	300/day/person	14	4200
	Harvesting + threshing		20	6000
	Irrigation		3	900
3	Electricity charges	7Rs/unit	270 units	1890
4	**Plant protection chemicals**			
	Thiamethoxam(insecticide)			350
	Imidacloprid			600
	Propiconazole			800
5	Tractor rent	2400/ha		2400
6	Field rent	75000/ha	6 months	37500
	Interest on working capital	12%		1800
	Total cost			59440

Table 15: Variable cost and grand total cost of cultivation

Treatments	Variable cost (Rs/ha)	Common cost of cultivation (Rs/ha)	Grand total (Rs/ha)
T1: 0% RDN + No biofertilizer	1240	59440	60680
T2: 0% RDN + PAU consortium	1365	59440	60805
T3: 0% RDN + Azotobacter	1640	59440	61080
T4: 0% RDN + Azospirillum	1590	59440	61030
T5: 50% RDN + No biofertilizer	2065	59440	61505
T6: 50% RDN + PAU consortium	2190	59440	61630
T7: 50% RDN + Azotobacter	2465	59440	61905
T8: 50% RDN + Azospirillum	2415	59440	61855
T9: 100% RDN + No biofertilizer	2890	59440	62330
T10: 100% RDN + PAU consortium	3015	59440	62455
T11: 100% RDN + Azotobacter	3290	59440	62730
T12: 100% RDN + Azospirillum	3240	59440	62680

Table 16: Gross returns, net returns and benefit-cost ratio

Treatments	Cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	B:C ratio
T1: 0% RDN + No biofertilizer	60680	76500.0	15820.0	1.26
T2: 0% RDN + PAU consortium	60805	77241.7	16436.7	1.27
T3: 0% RDN + Azotobacter	61080	77478.3	16398.3	1.27
T4: 0% RDN + Azospirillum	61030	77356.7	16326.7	1.27
T5: 50% RDN + No biofertilizer	61505	101779.2	40274.2	1.65
T6: 50% RDN + PAU consortium	61630	103646.7	42016.7	1.68
T7: 50% RDN + Azotobacter	61905	103136.7	41231.7	1.67
T8: 50% RDN + Azospirillum	61855	103531.7	41676.7	1.67
T9: 100% RDN + No biofertilizer	62330	126352.5	64022.5	2.03
T10: 100% RDN + PAU consortium	62455	129385.0	66930.0	2.07
T11: 100% RDN + Azotobacter	62730	129677.5	66947.5	2.07
T12: 100% RDN + Azospirillum	62680	130569.2	67889.2	2.08

6. Conclusion

All the biofertilizers irrespective of N levels, increased the plant height, dry matter accumulation, crop growth rate, leaf area, leaf area index, chlorophyll index and number of tillers significantly as compared to B0. Irrespective of biofertilizers, there was a significant increase in spike length, spike weight, number of spikelets / spike, number of grains / spike, yield, harvest index and 1000 seed weight at N50 compared to N0. There was further significant increase when N was increased to N100. All the biofertilizers irrespective of N levels, increased the spike length, spike weight, number of grains / spike, yield, harvest index significantly as compared to B0.the interaction between various levels of nitrogen and different biofertilizers was non-significant on spike weight, number of spikelets /spike, number of grains / spike, yield, harvest index and 1000 seed weight. BC, BA, BAZ were produced significantly higher biological yield when applied in combination with N50 which further significantly increased at N100. BC produced significantly higher spike length, number of grains / spike when applied in combination with N100 compared to N0 and N50. BA and BAZ produced significantly higher spike length when applied in combination with N50 which further significantly increased at N100.

Nitrogen use efficiency (NUE), N content and uptake by grain and straw: Irrespective of biofertilizers, there was a significant increase in N content in grain and straw, N uptake by grain and straw, recovery efficiency of N, agronomic efficiency of N at N50 compared to N0. There was further significant increase when N was increased to N100.

Higher gross returns (130569, 129677 and 129385 Rs / ha), net returns (67889, 66947 and 66930 Rs / ha) in N100 + BAZ, N100 + BA and N100 + BC. Highest benefit cost ratio (2.08, 2.07 and 2.07) were observed in N100 + BAZ, N100 + BA and N100 + BC. Different biofertilizers applied in combination with N100 resulted in better economic returns.

7. References

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