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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.) IN *HAPLUSTEPTS*

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ABSTRACT

A field experiment was conducted at Agronomy Farm, Rajasthan College of Agriculture, Udaipur during *rabi* season in 2013-14 and 2014-15. The results of the study showed that application of poultry manure @ 5 t ha^{-1} significantly increase the plant height (7.26, 38.54, 86.40 and 88.60 cm) dry matter accumulation (12.17, 54.86,143.22 and 196.84 g) at all stages of growth (30, 60, 90 and at harvest) ,Yield attributes (Effective tillers m^{-1} row length (107.25), number of grains ear^{-1} (42.40) and test weight (43.42 g)) and yield (grain (5.04 t ha^{-1}), straw (9.69 t ha^{-1}) and biological (14.73 t ha^{-1})). Further results showed that the enrichment of soil with 75 per cent RDF significantly increased the plant height (7.34, 38.37, 84.76 and 86.15 cm), dry matter accumulation (11.32, 53.03, 138.55 and 189.45 g), yield attributes (effective tillers m^{-1}row length (102.81), number of grains ear^{-1} (40.96) and test weight (42.66)) and (grain (4.84 t ha^{-1}), straw (9.24 t ha^{-1}) and biological (14.07)) yield over 50 per cent RDF and statistically at par with 100 per cent RDF and inoculations of seed with *Azotobacter* + PSB significantly increased the plant height (7.31, 38.67, 86.24 and 88.04 cm), dry matter accumulation (12.45, 53.93, 141.32 and 194.38 g), yield attributes (effective tillers m^{-1} row length (105.43), number of grains ear^{-1} (42.95) and test weight (43.12 g)) and (grain (5.01 t ha^{-1}), straw (9.65 t ha^{-1}) and biological (14.67 t ha^{-1})) yield of wheat crop. So results showed that 5 t ha^{-1} poultry manure + 75% NPK + dual inoculation of *Azotobacter* + PSB were gave significant yield over other treatments. There by a saving of 25% of nutrients

KEYWORDS: INM, growth parameters, yield attributes, yield, wheat.

INTRODUCTION

Wheat is one of the most important staple food crop of India and occupies a notable position among the food grain crops not only in area and production but also in its versatility in adaptation to a wide range of agro-climatic conditions. Wheat is the world's leading cereal crop cultivated over an area of about 216.06 m ha with a production of 655.49 mt. In India, the wheat production is about 95.85 mt from an area of around 30.61 m ha. In Rajasthan production of wheat is about 9.28 mt from an area around 3.06 m ha (Anon, 2014). Although, India is well placed in meeting its needs for food grains the major objective of food and nutritional security for its entire population has not been achieved. The demand for food grains is expected to rise not only as a function of population growth but also as more and more people cross the poverty line with economic and social development. The demand for wheat in India by 2020 has been projected to be between 105 to 109 mt as against 95.85 mt production of present day. Most of this increase in production will have to come from increased productivity, as the land area under wheat is not expected to expand. Efficient inputs management along with varietal improvement is the two basic aspects that can help us in achieving the target (Singh *et al.*, 2011). Enhanced use of chemical fertilizers for increasing production has been widely recognized but their indiscriminate use may have adverse effect on soil health, ecology and other natural resources, the high cost of fertilizer also restricts their large scale use. Therefore, to reduce dependence on chemical fertilizers and maintenance of high production levels are vital issues in modern agriculture which is only possible through integrated nutrient management (INM). Use of organic manures in INM helps in mitigating the multiple nutrient deficiencies. Addition of organic manures provides favorable environment for plant growth in addition to causing improvement in physical, chemical and biological properties of soil. Integrated nutrient management involves the integrated use of mineral fertilizers together with organic manure in suitable combination compliments and each other to optimize input use and maximize production and sustain the same without impairing the crop quality or soil health. It enables gainful utilization of organic wastes. (Dhaka *et al*, 2012)

The present study was designed to find out the effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.) in *Haplustepts* .

MATERIALS & METHODS

The experiment conducted during both the years was laid at Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur. The site was situated at 24º.35' N latitude, 74º.42' E longitude and an altitude of 579.5 m above mean sea level. The region falls under agro-climatic zone IVA (Sub-Humid Southern Plain and Aravalli Hills) of Rajasthan. The climate of the region is tropical characterized by mild winter and summer associated with high humidity particularly during July-September. The mean annual rainfall of the region ranges between 580-630 mm, most of which contributed by

South-West monsoon from July to September. In summers maximum temperature goes up to 44^{0}C. May and June are the hottest months. Winters are generally rainless and minimum temperature during December and January falls as low as 1^{0}C. The soil was Haplustepts, clay loam in texture having pH 7.69, EC 0.48 dS m^{-1}, Organic carbon 0.64%, available nitrogen 320.52kg ha^{-1}, available phosphorus 24.67 kg ha^{-1} and available potassium 310.15 kg ha^{-1}. The experiment was laid out in a split plot design with 27 treatment combinations which consisted of 3 organic manures (FYM @ 10 t ha^{-1}, Vermicompost @ 4 t ha^{-1} and Poultry manure @ 5 t ha^{-1}), 3 levels of inorganic fertilizers (50% RDF, 75% RDF and 100% RDF) and 3 levels of biofertilizers (*Azotobacter*, PSB and *Azotobacter* + PSB)were replicated three times. Wheat (Raj 4037) was sown during second week of Novemember and harvested in the first week of April. Growth parameters (Plant height at 30. 60, 90 and at harvest, dry matter accumulation at 30, 60, 90 and at harvest), yield attributes (Effective tillers m^{-1} row length, number of grains ear^{-1} and test weight) and yield (grain, straw and biological) were recorded.

RESULTS & DISCUSSION

Effect of organic manures

Growth

The organic manures in addition to nutrients contain microbial load and growth promoting substances which helps in improving the metabolic activity and plant growth. The results showed that application of different type of organic manures significantly altered the biomass production of wheat at all growth stages. All the components of plant biomass were favorably influenced by the application of organic manures for instance, plant height in cm (Table 1) and dry matter accumulation g $meter^{-1}$ row length (Table 2). An application of poultry manure @ 5 t ha^{-1} was recorded (7.26, 38.54, 86.40 and 88.60 cm) significantliy higher plant height over FYM @10 t ha^{-1} and statistically at par with vermicompost @ 4 t ha^{-1}. Application of poultry manure @5 t ha^{-1} recorded (12.17, 54.86, 143.22 and 196.84 g) significantly higher dry matter accumulation than both the treatments *i.e.* FYM @ 10 t ha^{-1} and vermicompost @ 4t ha^{-1} respectively.

The biological manure has many attributes. It supplies a wide variety of nutrients along with organic matters that improved the physical properties of soil. Its beneficial effects some time difficult to duplicate with other materials (Pong and laty, 2000). Organic matter is very important for the growth of many plants because it improves the growth of plants directly or indirectly. Large amount of macro nutrients and micro nutrients are present in the organic matter and humic is a substance which is produce in the soil by the decomposition of organic material and this material is very useful for the growth of the plant (Noreen and Noreen, 2014). Application of various organic manures stimulated the plant growth, activity of soil microorganisms and higher activity of soil enzymes (Knapp *et al.,* 2010).The higher plant height and dry matter accumulation in poultry manure and vermicompost may be due to the fact that in poultry manure mineralization is rapid , large portion of nitrogen in poultry manure is inorganic fractions, but 20 to 40 per cent of the total is in organic (Channabasanagowda *et al.,* 2008). Whereas vermicompost increases the population of beneficial microorganisms such as N-fixers, P- solublizers and increase nitrogenase and urease enzyme activity (Channabasanagowda *et al,* 2008).

Yield attributes and yield

Organic manures such as FYM, vermicompost and poultry manure which are renewable and eco-friendly to achieve sustainable productivity with minimum deterioration effect of chemical fertilizers on soil health and environment. It was observed that highest effective tillers $meter^{-1}$ row length (107.25), grains ear^{-1} (42.40) and test weight (43.42 g) were found with the application of 5 t ha^{-1} poultry manure (Table 3). The advantage of organic manures is quite obvious, as these provide a steady supply of nutrients leading better growth of plants. Moreover, the increased availability of P and K in addition to other plant nutrients released by the organic manures might have contributed in enhancing the yield-attributes. The positive impact of availability of individual plant nutrients and humic substances from manure and balanced supplement of nitrogen through inorganic fertilizers might have induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of yield parameters (Sharma *et al.,* 2013).

Results revealed that application of different organic manures significantly increased the grain, straw and biological yield. Highest grain yield (5.04 t ha^{-1}), straw yield (9.69 t ha^{-1}) and biological yield (14.73) were found with the application of 5 t ha^{-1} poultry manure than other treatments (Table 4 and Fig 1). Poultry manure was reported the best sources among all the organic sources because of higher concentration of N that is readily available to crop. It was observed that approximately 40 % of total N and 74 % of total P in poultry manure would be in available form (Kumar and Pannu, 2012). The higher yield may be due to fact that these organic manures supplies direct available nutrients such as nitrogen to the plants and improve the proportion of water stable aggregates of the soil. This was attributed to cementing action of polysaccharides and other organic compounds released during the decomposition of organic matters, thus leading to taller plants, increased tillers and final yield (Hendrix *et al.,* 1994 and Martens *et al.,* 1992). The significant increase in grain and straw yields under the influence of poultry manure was largely a function of improved growth and consequent increase in different yield attributes as mentioned above. The possible reason could be ascribed to the favorable effect on soil properties due to formation of more humus colloidal complex coupled with higher nutrient content of poultry manure (Dhaka *et al.,* 2012). Another fact that the presence of uric acids in poultry manure that hastens the release of nutrients from poultry manure than compost and cow dung so easy and readily available of nutrients to plant and it increased the yield attributes and yield of crop (Islam *et al.,* 2014).

TABLE 1: Effect of organic manures, fertilizer levels and biofertilizers on plant height at different stages

Treatments	Plant height (cm) at 30 DAS			Plant height (cm) at 60 DAS			Plant height (cm) at 90 DAS			Plant height (cm) at harvest		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Organic manures												
FYM(10 t ha^{-1})	6.11	7.34	6.72	35.34	37.07	36.21	79.82	83.26	81.54	80.91	84.23	82.57
VC(4 t ha^{-1})	6.39	7.85	7.12	36.77	38.18	37.47	81.83	86.41	84.12	84.29	87.40	85.84
PM(5 t ha^{-1})	6.50	8.02	7.26	37.39	39.69	38.54	84.25	88.55	86.40	87.37	89.82	88.60
SEm ±	0.085	0.151	0.087	0.551	0.569	0.396	1.161	1.274	0.862	1.348	1.366	0.960
CD (P = 0.05)	0.256	0.454	0.250	1.652	1.705	1.141	3.480	3.818	2.482	4.042	4.094	2.764
Fertilizer levels												
50% NPK	6.14	6.60	6.37	34.49	35.49	34.99	79.24	83.22	81.23	81.17	84.49	82.83
75% NPK	6.40	8.29	7.34	37.36	39.37	38.37	82.88	86.64	84.76	85.27	87.02	86.15
100% NPK	6.46	8.31	7.38	37.64	40.09	38.87	83.78	88.37	86.08	86.13	89.93	88.03
SEm ±	0.085	0.151	0.087	0.551	0.569	0.396	1.161	1.274	0.862	1.348	1.366	0.960
CD (P = 0.05)	0.256	0.454	0.250	1.652	1.705	1.141	3.480	3.818	2.482	4.042	4.094	2.764
Biofertilizers												
Azotobacter	6.24	7.64	6.94	36.35	37.91	37.13	80.95	85.13	83.04	83.14	86.18	84.66
PSB	6.15	7.57	6.86	35.20	37.64	36.42	80.71	84.85	82.78	82.64	85.98	84.31
*Azotobacte*r + PSB	6.61	8.00	7.31	37.94	39.39	38.67	84.24	88.24	86.24	86.79	89.28	88.04
SEm ±	0.081	0.113	0.070	0.389	0.387	0.274	0.765	0.678	0.511	0.805	0.828	0.577
CD (P = 0.05)	0.233	0.325	0.196	1.115	1.111	0.773	2.195	1.945	1.441	2.308	2.374	1.627

TABLE 2: Effect of integrated nutrient management on dry matter accumulation at different stages

Treatments	DMA (g) at 30 DAS			DMA (g)) at 60 DAS			DMA (g) at 90 DAS			DMA (g) at harvest		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Organic manures												
FYM(10 t ha^{-1})	9.76	10.12	9.94	47.24	51.87	49.56	126.80	133.43	130.12	175.70	181.63	178.66
VC(4 t ha^{-1})	10.65	11.22	10.93	50.57	53.00	51.78	131.85	140.09	135.97	186.06	187.75	186.91
PM(5 t ha^{-1})	11.71	12.63	12.17	53.31	56.41	54.86	139.15	147.29	143.22	196.34	197.34	196.84
SEm ±	0.221	0.241	0.163	0.895	0.936	0.647	2.164	2.374	1.606	3.289	3.172	2.285
CD (P = 0.05)	0.663	0.722	0.471	2.682	2.807	1.865	6.488	7.119	4.627	9.859	9.511	6.581
Fertilizer levels												
50% NPK	9.85	10.07	9.96	46.95	51.50	49.22	127.33	129.85	128.59	174.70	181.35	178.02
75% NPK	11.02	11.63	11.32	51.85	54.21	53.03	133.00	144.11	138.55	187.81	191.09	189.45
100% NPK	11.25	12.27	11.76	52.33	55.57	53.95	137.47	146.85	142.16	195.60	194.28	194.94
SEm ±	0.221	0.241	0.163	0.895	0.936	0.647	2.164	2.374	1.606	3.289	3.172	2.285
CD (P = 0.05)	0.663	0.722	0.471	2.682	2.807	1.865	6.488	7.119	4.627	9.859	9.511	6.581
Biofertilizers												
Azotobacter	10.16	10.47	10.32	49.71	53.16	51.44	130.61	138.18	134.40	183.87	185.72	184.79
PSB	10.14	10.40	10.27	49.41	52.26	50.84	130.07	137.10	133.59	182.36	184.12	183.24
*Azotobacte*r + PSB	11.81	13.10	12.45	52.00	55.86	53.93	137.12	145.53	141.32	191.87	196.89	194.38
SEm ±	0.218	0.156	0.134	0.651	0.889	0.551	2.092	1.592	1.315	2.009	2.342	1.543
CD (P = 0.05)	0.625	0.447	0.378	1.867	2.550	1.553	6.001	4.567	3.706	5.761	6.718	4.349

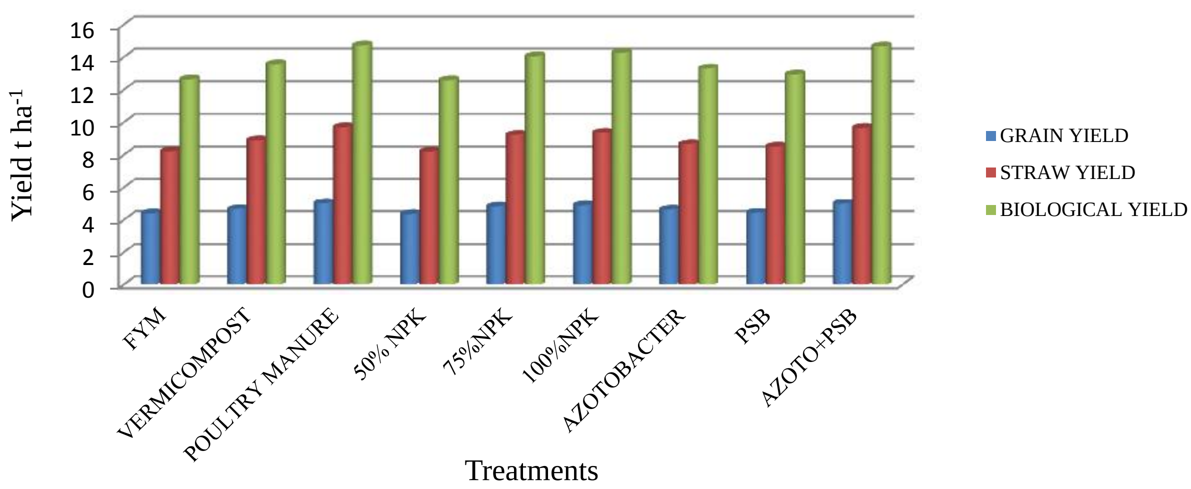
TABLE 3: Effect of integrated nutrient management on effective tillers, no. of grains per ear and test weight of wheat

Treatments	Effective Tillers m^{-1} row length			No. of grains ear^{-1}			Test weight (g)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Organic manures									
FYM(10 t ha^{-1})	98.16	100.80	99.48	38.14	40.89	39.51	39.71	40.30	40.01
VC(4 t ha^{-1})	100.93	101.89	101.41	40.19	41.17	40.68	42.07	42.72	42.40
PM(5 t ha^{-1})	106.79	107.71	107.25	41.88	42.91	42.40	43.23	43.61	43.42
SEm ±	1.633	1.719	1.186	0.419	0.517	0.333	0.532	0.514	0.370
CD (P = 0.05)	4.895	5.154	3.415	1.256	1.550	0.958	1.596	1.540	1.065
Fertilizer levels									
50% NPK	98.74	99.54	99.14	39.09	40.70	39.90	39.94	40.77	40.35
75% NPK	102.00	103.62	102.81	40.54	41.38	40.96	42.46	42.87	42.66
100% NPK	105.13	107.24	106.19	40.58	42.89	41.73	42.61	43.01	42.81
SEm ±	1.633	1.719	1.186	0.417	0.517	0.333	0.532	0.514	0.370
CD (P = 0.05)	4.895	5.154	3.415	1.256	1.550	0.958	1.596	1.540	1.065
Biofertilizers									
Azotobacter	101.92	103.01	102.47	39.00	40.96	39.98	41.07	41.80	41.43
PSB	99.14	101.34	100.24	38.80	40.52	39.66	40.98	41.57	41.27
Azotobacter + PSB	104.82	106.05	105.43	42.41	43.49	42.95	42.96	43.28	43.12
SEm ±	0.977	1.039	0.713	0.416	0.483	0.319	0.420	0.447	0.307
CD (P = 0.05)	2.802	2.979	2.010	1.193	1.386	0.899	1.205	1.282	0.865

TABLE 4: Effect of integrated nutrient management on grain yield, straw yield, biological yield and harvest index of wheat

Treatments	Grain Yield (t ha^{-1})			Straw Yield (t ha^{-1})			Biological Yield (t ha^{-1})			Harvest Index (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Organic manures												
FYM(10 t ha^{-1})	4.15	4.64	4.40	8.32	8.14	8.23	12.47	12.79	12.63	33.63	36.50	35.06
VC(4 t ha^{-1})	4.40	4.94	4.67	8.49	9.31	8.90	12.88	14.25	13.57	34.10	34.91	34.51
PM(5 t ha^{-1})	4.63	5.44	5.04	9.50	9.88	9.69	14.14	15.33	14.73	32.96	35.76	34.36
SEm ±	0.083	0.111	0.069	0.172	0.183	0.126	0.222	0.233	0.161	0.464	0.625	0.389
CD (P = 0.05)	0.248	0.331	0.199	0.516	0.550	0.362	0.666	0.698	0.463	NS	NS	NS
Fertilizer levels												
50% RDF	4.04	4.68	4.36	8.14	8.30	8.22	12.18	12.98	12.58	33.31	36.08	34.69
75% RDF	4.54	5.13	4.84	8.98	9.49	9.24	13.53	14.62	14.07	33.77	35.52	34.64
100% RDF	4.60	5.22	4.91	9.18	9.54	9.36	13.78	14.76	14.27	33.60	35.58	34.59
SEm ±	0.083	0.111	0.069	0.172	0.183	0.126	0.222	0.233	0.161	0.464	0.625	0.389
CD (P = 0.05)	0.248	0.331	0.199	0.516	0.550	0.362	0.666	0.698	0.463	NS	NS	NS
Biofertilizers												
Azotobacter	4.28	5.01	4.65	8.42	8.91	8.67	12.70	13.92	13.31	33.92	36.37	35.14
PSB	4.16	4.72	4.44	8.19	8.82	8.50	12.35	13.55	12.95	33.68	35.00	34.34
*Azotobacte*r + PSB	4.74	5.29	5.01	9.70	9.61	9.65	14.44	14.89	14.67	33.09	35.80	34.45
SEm ±	0.080	0.083	0.058	0.154	0.125	0.099	0.195	0.149	0.123	0.447	0.537	0.349
CD (P = 0.05)	0.228	0.239	0.162	0.441	0.358	0.279	0.559	0.426	0.346	NS	NS	NS

FIGURE: 1 Effect of organic manures, fertilizer levels and biofertilizers on grain , straw and biological yield (t ha^{-1}) of wheat (Pooled)



Effect of fertilizer levels

Growth

Chemical fertilizers place an important role in the growth of any crop plants. It is evident from the results that fertilizer levels significantly increased plant height (7.34, 38.37, 84.76 and 86.15 cm) and dry matter accumulation m^{-1} row length (11.32, 53.03, 138.55 and 189.45 g) at different growth stages at 30, 60, 90 DAS and at harvest (Table 1 to 2). Results showed that successive application of recommended dose of fertilizer at 75% level significantly increased the biomass production over 50 % but at par with 100% level at all growth stages. It was found from the results that all the components of plant biomass favorably influenced by the application of fertilizer. Overall improvement in growth of plants under the influence of increasing rates of fertilizer levels could be ascribed to potential role of N, P and K fertilizer in modifying soil and plant environment conducive for better development of morphological components of the growth. Nitrogen plays a vital role in growth processes as it is an integral part of chlorophyll, protein and nucleic acid. It is viewed as the central element because of its role in substance synthesis. It constitutes 1.5 to 5 percent of the dry weight of higher plant. Further, phosphorus fertilization improves various metabolic and physiological processes, thus known as "Energy currency" which is subsequently used for vegetative and reproductive growth through phosphorylation (Brady, 1996 and Tisdale, 2002). An adequate supply of phosphorus early in the life of a plant is important in laying down the primordial for its reproductive parts.

Phosphorus also increases the initiation of both first and second order rootlets and their development. The extensive root system helps in exploiting the maximum nutrients and water from soils (Tandon and Narayan, 1990). Potassium (K^+) is of unusual significance because of its live role in biochemical functions of the plant like activating various enzymes, improvement of protein, carbohydrates and fat concentration, developing tolerance against drought and resistance to frost, lodging, pests and disease attack. Potassium is one of the major essential plant nutrient required for normal growth and development of plants. The improvement in nutritional status of plant might have resulted in greater synthesis of amino acids and protein and other growth promoting substances which seems to have enhanced the maristematic activity and increased cell division and enlargement and their elongation resulting in higher plant height. The results of present investigation are in close conformity with findings of several researchers (Singh *et al*., 2012). 100 per cent NPK in wheat showed beneficial effect on plant height and dry matter accumulation at harvest in wheat. These results similarly supported by (Bandyopdhyay *et al.,* 2009).

Yield attributes and yield

Maintaining soil fertility and use of plant nutrients in sufficient and balanced amounts is one of the key factors in increasing crop yield. Application of recommended dose of fertilizer significantly increased the grain, straw and biological yield of wheat except the harvest index. Results showed that the maximum grain yield (4.84 t ha^{-1}), straw yield (9.24 t ha^{-1}) and biological yield (14.07 t ha^{-1}) were found with the application of 75% RDF which was significantly higher with the 50% RDF and statistically at par with 100% RDF (Table 4). Grain yield of wheat is chiefly a product of yield attributing characters *viz*, effective tillers m^{-1} row length, number of grain ear^{-1} and test weight significantly increased up to 100 % level of fertilizer. Maximum effective tillers m^{-1} row length (102.81), number of grain ear^{-1} (40.96) and test weight (42.66 g) were found with the application of 75% RDF which was significantly higher with the 50% RDF and statistically at par with 100% RDF (Table 3). Application of fertilizers has supplied adequate amount of nutrients that helped in expansion of leaf area which might have accelerated the photosynthesis rate and in turn increased the supply of carbohydrates to the plants. Similar results reported by (Jat *et al*., 2014 and Chauhan, 2014). Significant increased in grain yield and biological yield of wheat with increased levels of fertilizers might be due to improvement in yield attributes i.e. increased plant height and profused tillering (Jat *et al*., 2014). The combined use of NPK fertilizers plays an important role in wheat production. Application of NPK in balanced share at proper time has great impact on wheat yield. The optimum use of fertilizers is achieved to maintain the balanced management of the crop for better yield. Similarly these results supported by (Bandyopdhyay *et al*., 2009 and Khare and Dixit, 2011).

Effect of biofertilizers

Growth

Biofertilizers are minute organisms which are beneficial to the plant growth. Seed inoculation with biofertilizers significantly influenced all the growth parameters. Dual inoculation of *Azotobacter* + PSB was found significant with respect of all the growth parameters over single inoculation. (Table 1 to 2)

Biofertilizer as a substance containing living microorganisms which, when applied to seed colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. It is an established fact that micro-organism assimilate atmospheric nitrogen through enzyme nitrogenase in bacterial cells. The fixed organic nitrogen in becterioeds is dissociated and later on oxidized to nitrate (NO_3) form. The increased endogenous nitrogen content due to inoculation might have promoted crop growth. In addition to this *Azotobacter* has ability to produce antifungal, antibodies and similar compounds against pathogen like *Fusarium* and *Alternaria*. Thus, beneficial effects of *Azotobacter* inoculation could be attributed to their multiple action for synthesise growth promoting substances, antifungal and antibiotics which might have been utilized by the plants in synthesis of protein, carbohydrates, starch and other assimilates, thereby improving growth of plant. Inoculation with PSB enhances availability of P through solubilization of insoluble phosphorus carriers such as calcium and magnesium phosphate through production of organic acids like malic, glyoxalic, succinic, fumaric and citric acid. Under present investigation, distinct superiority of *Aztobacter* + PSB in improving growth could be ascribed to the better establishment of microorganism population in the rhizosphere besides providing physical properties of soil and also ensured availability of nutrients through PSB, which enhanced availability of phosphorus from soil. It has been well emphasized that dual inoculation played vital role in improving three major aspects of yield determination i.e. formation of vegetative structure for higher photosynthesis, strong sink strength through development of reproductive structure and production of assimilates to fill economically important sink. (Kaushik *et al.*, 2012)

Yield attributes and yield

The addition of biofertilizers, *i.e.* live microorganisms (bacteria, fungi) known to improve plant growth and crop productivity. Results showed that dual inoculation of biofertilizers (*Azotobacter* + PSB) significantly affect the yield attributes and yield of wheat. Highest number of tillers meter^{-1} row length (105.43), number of grains ear^{-1} (42.95), test weight (43.12 g), grain yield (5.01 t ha^{-1}), straw yield (9.65 t ha^{-1}) and biological yield (14.67 t ha^{-1})were found with the dual inoculation of *Azotobacter* + PSB rather than single inoculation (Table 3 and 4).

The biofertlizer application significantly improved grain and straw yield of wheat. (Malik *et al*, 2009). Biofertilizers can play an important role in meeting the nutrient requirement of crops because they can be produced at a low cost and can meet a part of nutrient requirements for increased crop production. They enhance soil fertility also crop productivity by fixing atmospheric nitrogen, mobilizing sparingly soluble P and by facilitating the release of nutrients through decomposition of crop residues. *Azotobacter* and *phosphobacteria* produce growth hormones *viz*., Indole acetic acid and Gibberellins. These hormones stimulate root growth and development. The use of growth stimulating seed inoculants helps to accelerate uptake of plant nutrients from applied chemical fertilizers by increasing the root growth. The significant increase in straw yield under dual inoculation of *Azospirllum*+PSB seems to be due to their direct effect in improving biomass plant^{-1}, while indirect effect might be on account of increase in morphological parameters. (Kaushik *et al.*, 2012 and Ram and Mir, 2006). However, when N_2 fixers and PSB were used together there was significant additive effect. Single inoculation treatments, *A. Chroococcum* significantly increased the grain and straw yield of wheat by 197%, and 42%, respectively relative to control while dual inoculation with *A. Chroococcum* in association with *Pseudomonas strita* further enhance grain and straw yields by 230% and 50%, respectively (Zaidi and Khan 2005).

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