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Effect of fertility levels and liquid biofertilizers on growth and yield of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment entitled "Effect of Fertility Levels and Liquid Biofertilizers on Growth and Yield of Wheat (*Triticum aestivum* L.)" was conducted during *Rabi* 2019 at Instructional Farm of Agronomy, Rajasthan College of Agriculture, Udaipur**.** The experiment consisted of 16 treatments combinations comprising of four levels of fertility (Control, 75, 100 and 125% RDF) and four levels of liquid biofertilizers (Control, *Azotobacter,* PSB and *Azotobacter* + PSB). Experiment was conducted under factorial randomized block design replicated thrice taking wheat var. Raj.-4238 as test crop. The Recommended dose of fertilizer (RDF) was 100:60:40 kg ha^{-1} of N:P_2O_5:K_2O. Results showed that significant increase in plant height, total tillers m^{-1} row length, effective tillers m^{-1} row length, test weight, grain, straw and biological yield was observed with the combine application of 100% RDF and *Azotobacter* + PSB.

Keywords: Fertility, liquid, biofertilizers, wheat, *Triticum aestivum* L.

Introduction
In India, it is occupied over 29.55 million hectare area (13.43% of global area) with a production level of about 101.20 million tonnes (12.96% of world production) of grain with a productivity of 3424 kg ha^{-1} (Anonymous, 2019) [2]. In Rajasthan, it is occupied an area of 2.88 million hectare with a production of 9.60 million tonnes of grain with a productivity 3334 kg ha^{-1} (Anonymous, 2019) [2]. Nitrogen is an essential plant nutrient and has significant role in plant growth. It is a constituent of protein and amino acids (Gul *et al*., 2015) [11]. Nitrogen plays a most important role in biochemical and physiological functions of plants. It also increases process of photosynthesis, dark-green colour in plants leaf area duration, leaf area production and net assimilation rate, stem and growth and development of other vegetative parts and enhance the protein content of fodder crop. It improve the food quality and enhances the crop yield (Leghari *et al*., 2016, Bloom, 2015 and Hemerly, 2016) [22, 6, 13]. Phosphorus is an integral nutrient element in the plant system. It is known as "key of life" because in the deficiency of this single element, plants cannot complete their life cycles. It is essential for cell enlargement, cell division, energy storage and transfer, enhancing seed maturity and seed development, photosynthetic activity and transport to the ripening grains (Ziadi *et al*., 2008, Hadis *et al*., 2018) [44, 12]. It is a constituent of energy rich compounds *viz.* ATP and ADP, NADP, phytin, nucleic acid, phospholipids. (Abdel-Aziz *et al*., 2018) [1]. Potassium is an activator of enzymes which involved in plant growth. It plays important role in stomatal activity, transport of sugars, water and nutrient, synthesis of protein and starch (Prajapati *et al*., 2012) [25]. Potassium increases drought tolerance and resistance to insect, pests, frost, lodging and diseases incidence (Wang *et al*., 2013) [40]. Conventional agriculture plays a significant role in providing the food for growing human population, which has also led to growing reliance on pesticides and chemical Fertilizers (Santos *et al*., 2012) [30]. Indiscriminate and unbalanced use of chemical fertilizers, especially urea, along with chemical pesticides and lack of organic manure supply has led to considerable reduction in the health of soil. The exploitation of phosphorus and nitrogen fertilizers causes air and ground water pollution by eutrophication of water bodies (Youssef *et al*., 2014) [43]. This circumstance leads to the introduction of harmless inputs like Biofertilizers. Biofertilizers play important role in maintaining long term soil fertility and sustainability by fixation of atmospheric dinitrogen (N=N), convert insoluble P into available form or mobilizing fixed macro and micro nutrients for plants, there by increases their efficiency and availability (Venkatashwarlu, 2008) [38].

Biofertilizers keep the soil environment rich in all kinds of macro- and micro-nutrients via fixation of nitrogen, phosphate and potassium, mineralization or solubilisation, production of antibiotics, release of plant growth regulating substances and biodegradation of organic matter in the soil (Sinha *et al.*, 2014) [34]. They are eco-friendly and low cost inputs and can reduce chemical fertilizer dose by 25-50% (Vance, 1997 and Rana *et al.*, 2012) [36, 28]. Liquid inoculants are specially formulated in appropriate nutrient medium containing certain cell protecting chemicals of viable cells of desired micro-organisms. These chemicals encourage the survival of cell during storage and after seed application. It also protect microbial cells under extreme soil conditions, such as desication and high temperature. Liquid inoculants being the new advance in biofertilizers technology, the current research was conducted to study the impact of different levels and methods of application of carrier and liquid bioinoculants of *Azotobacter* sp. and PSB in combination with chemical fertilizers on wheat production under field conditions (Khandare *et al*., 2015) [18]. The liquid biofertilizers have the high population of micro-organisms up to 10^9 cells per ml for 12 to 24 months and their dose is 10 times lesser on carrier based biofertilizers. The proper use of liquid biofertilizers increases the soil quality and crop yield as compared to carrier-based biofertilizers (Verma *et al*., 2018) [39]. The liquid bio-fertilizers reduce the cultivation cost by avoiding processing and sterilization of carrier-based products. They need less labour, resources and handling space than carrier-based formulation (Velineni and Brahmaprakash 2011) [37]. *Azotobacter* is a free-living nitrogen fixing bacteria which play a vital role in the nitrogen cycle in nature as it has a number of metabolic functions (Sahoo *et al.*, 2013) [29]. *Azotobacter* is a plant growth promoting rhizobacteria (PGPR) which stimulate plant growth by facilitating the plant's uptake of certain nutrients from the environment (Joseph *et al*., 2007) [15] or enzyme ACC (1-aminocyclopropane-1-carboxylate) deaminase (Shaharoona *et al*., 2006). *Azotobacter* also has the capacity to produce vitamins such as riboflavin, thiamine and plant hormones *viz.*, indole acetic acid (IAA), cytokinins (CK) and gibberellins (GA) (Bhardwaj *et al*., 2014) [4]. Phosphate solubilizing bacterias (PSB) are beneficial micro-organisms which have the capacity to solubilize organic compounds by the production of phosphatases such as phytase into inorganic phosphorus compounds. The major phosphate solubilising genera include Bacillus and Pseudomonas, they constitute about 1–50% of the total microbial population in soil (Kalayu, 2019) [16].

Materials and Methods

Description of the study area

The experiment was carried out at the Agronomy Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur. The site was situated at 24°35' N latitude, 73°42' E longitude and an altitude of 582.17 meters above sea level in the south-eastern part of Rajasthan. The region falls under Rajasthan's agro-climatic zone IVA (Sub-Humid Southern Plain and Aravalli Hills). During cropping period of wheat, the corresponding mean weekly temperature fluctuations were observed during *Rabi* season in year 2019, maximum and minimum temperature ranged between 37.3 °C and 20.8 °C, respectively. Mean weekly maximum and minimum relative humidity ranged between 86.7 and 16.7 per cent, respectively. Total rainfall and maximum evaporation were 42.6 and 9.9 mm was recorded during crop season.

The soil analysis confirmed that soil of experimental field was clay loam belongs to *Typic Haplustepts*, neutral alkaline in reaction, medium in available nitrogen and phosphorus and high in available potassium. Soil was low in available zinc and iron.

Experimental design and procedure

The experiment consisted of 16 treatments combinations comprising of four levels of fertility (Control, 75, 100 and 125% RDF) and four levels of liquid biofertilizers (Control, *Azotobacter*, PSB and *Azotobacter* + PSB). Experiment was laid out in factorial randomized block design replicated thrice. In wheat crop as per treatment required dose of nitrogen by subtracting the amount of N supplied through DAP and remaining by urea, P_2O_5 through DAP and K_2O through MOP was applied to the crop. At the time of sowing, half dose of nitrogen, full dose of phosphorus, potassium and half dose of nitrogen was applied before the sowing and remaining half dose of nitrogen was applied in two equal splits during 1st and 3rd irrigation. The seed treatment with liquid biofertilizers done with using a plastic bag. The bag filled with 1 kg of seeds and required amount of biofertilizers (@ 5 to 10 ml kg^{-1} seed of each biofertilizers) was added. Then bag closed and squeezed until all the seeds were evenly wetted. The bag was opened and seeds dried for 20 to 30 minutes in the shade. There are plots in which seeds are treated with *Azotobacter* and PSB alone and some plots which are treated with both.

Result and Discussion

Effect of fertility levels

Growth parameter

The results of the investigation presented in Table 3.1 showed that the significant improvement in plant height (30 DAS, 60 DAS and at harvest) and were observed with application of different levels of fertility. The plant height increased to each higher level of fertility up to 100% RDF but it remained at par with 125% RDF. The increase in plant height with increase in fertility levels due to higher availability of nutrients to plant which might have enhanced growth substances and phytohormones. The higher nutrient availability in rhizosphere for plant growth at active vegetative stages which seem to have promoted metabolic activities (Choudhary and Yadav, 2011) [9]. As nitrogen is one of essential and major plant nutrient required for growth and development, increased availability of nitrogen improves the plant height by increased cell number and cell elongation (Bloom, 2015) [6]. Similarly, increased supply of available phosphorus enhances formation of new cells, promotes plant vigor and better utilization of nitrogen also. The energy gained from photosynthesis, enzyme activation /inactivation and carbohydrates metabolism stored in storage compound (ATP and ADP) for later use might have resulted in vigorous growth of plants (Rahman *et al.*, 2016) [26]; Tiwari and Kumar (2009) [35]. Xu *et al.*, (2020) [42] reported that Potassium has significant effect on the growth and development of plant roots. Potassium act as an enzyme activator, play an important role in protein synthesis of N and C metabolism, sugar transport and photosynthesis. Thus, application of NPK fertilizers in balanced proportion increased the plant height. The effect of fertility levels on plant height also corroborates with Kumar and Pannu, (2012) [19].

Yield attributes and Yield

The results of plant mean (Table 1 and 2) indicate that the application of different fertility levels significant improve the yield attributes. Yield and yield attributes *viz.* total tillers meter^{-1} row length, effective tillers m^{-1} row length and test weight increased to each higher level of fertility up to 100% RDF but it remained at par with 125% RDF. The highest yield attributes were observed that with the application of 100% RDF. The increase in yield attributes with increase in fertility levels due to cumulative effect on growth and vigour of plants. The continuous availability of nitrogen, phosphorus and potassium in plant at all critical stages, which might have resulted in higher photosynthesis, better root development which increased the higher supply of photosynthates from source to sink (total tillers meter^{-1} row length, effective tillers m^{-1} row length and test weight) (kumawat *et al.*, 2013) [21]. The grain and stover yield significantly influenced with application of different fertility levels might be due to improvement in yield attributes and cumulative interaction between vegetative and reproductive growth of the crop (Mathur *et al.*, 2007) [23]. The significant increase in stover yield due to application of 100% RDF could be ascribed to the increased vegetative growth resulted effective utilization of nutrients absorbed through extensive root system developed due to phosphate fertilization (Singh *et al.*, 2018). Biological yield is a function of grain and stover yields. Thus, significant increase in biological yield with the application of 100% RDF could be attributed due to increased grain and stover yield Table 4.2 Choudhary *et al.*, (2017) [10].

Effect of liquid biofertilizers

Growth parameter

It is cleared from the data presented in Table 3.1 that plant height (30 DAS, 60 DAS and at harvest) of wheat was significantly affected by inoculation of seed with different liquid biofertilizers *viz., Azotobacter,* PSB and *Azotobacter* + PSB as compared to control. The highest plant height (30 DAS, 60 DAS and at harvest) were observed with combine inoculation of *Azotobacter* + PSB over control and single inoculation. Biofertilizers improve growth might be due to increasing the supply or availability of plant nutrients. The inoculation of seed with nitrogen fixer have increased the concentration of *Azotobacter* in the rhizosphere and they fixed atmospheric and organic nitrogen in becterioeds and later on oxidized to nitrate form. *Azotobacter* increases the root development and plant growth might be due to excretion of vitamins, auxins and amino acids (Mohanta *et al.*, 2020). Chand *et al.*, (2014) [24, 8] reported that PSB produced organic acids like malic, succinic, glyoxalic, fumaric and critic acid, which have increased the mineralization of insoluble organic phosphorus to soluble phosphorus there by increased the availability of P in soil. Singh and Prasad (2011) [33] reported that *Azotobacter* and PSB application have beneficial effects on wheat and they could be attributed to their ability to fix atmospheric nitrogen, phosphate solubilization and secretion of plant growth hormones (Khandare *et al.* 2015) [18]. Prolification of lateral root and root hairs that provided more surface area for nutrient and water absorption this might be due to increase in plant growth by combine inoculation of *Azotobacter* and PSB. Hence, plant height increased due to photosynthesis and production of assimilates which is enhanced by prolificated growth. These results are in similar with the findings of Bai *et al.*, (2003) and Wu *et al.*, (2005) [3, 41].

Yield attributes and Yield

The results of the investigation presented (Table 3.1 and 3.2) showed that yield attributes and yield except harvest index was significantly affected by inoculation of seed with different liquid biofertilizers *viz., Azotobacter,* PSB and *Azotobacter* + PSB as compared to control. Inoculation of biofertilizers could not have any significant effect on harvest index. The highest yield attributes *viz.* total tillers meter^{-1} row length, effective tillers m^{-1} row length and test weight were observed with combine inoculation of *Azotobacter* + PSB over control and single inoculation. Jnawali *et al.*, (2015) [14] reported that increase in yield due to seed inoculation with *Azotobacter* supply more nitrogen to the crop and ultimately increase in yield. Chelating effect of PSB reduces the phosphorus fixation and solubilized the fixed form of phosphorus leading to more uptake of phosphorus and resulted better growth attributed *viz.* total tillers meter^{-1} row length, effective tillers m^{-1} row length and test weight. Uptake of micronutrient and secondary nutrients enhanced due to greater expansion of roots under increased availability of phosphorus might have enhanced photosynthates and their partitioning among vegetative and reproductive plant parts which ultimately improve the yield attributes and lastly the seed yield. The cumulative effect of increased growth and yield attributes might have enhanced in seed and stover yield (Selvakumar *et al.* 2012) [31]. The combine inoculation of N+P-fixer have synergistic effect on the production of growth promoting hormones such as auxin, gibberellins and cytokinin might have enhanced yield attributes and yield (Kaushik *et al.*, 2012) [17]. Combine inoculation of *Azotobacter* + PSB increased stover yield might be due to increase in biomass production. Kumawat and Khangarot (2002); Brahmaparkash *et al.*, (2004); Ram and Mir, (2006); Singh *et al.*, (2008) and Bhavya *et al.*, (2017) [20, 7, 27, 32, 5].

Table 1: Effect of fertility levels and liquid biofertilizers on growth and yield attributes

Treatments	Plant height (cm)			No. of total tillers (per meter row length)	No. of effective tillers (per meter row length)	Test weight (g)
	At 30 DAS	At 60 DAS	At harvest			
Fertility levels (RDF)						
Control (F_0)	34.90	62.24	84.22	77.33	62.95	37.24
75% RDF (F_1)	41.8	71.69	94.15	87.23	71.85	41.34
100% RDF (F_2)	44.1	77.49	100.91	95.25	76.47	43.9
125% RDF (F_3)	44.9	79.3	102.3	96.1	77.23	44.2
S.Em±	0.68	1.85	2.27	2.51	1.58	0.85
C.D.5%	1.97	5.36	6.55	7.25	4.58	2.47
Biofertilizers						
No inoculation (B_0)	34.89	63.22	86.72	79.79	65.42	38.33
Azotobacter (B_1)	41.05	71.69	93.2	85.26	69.5	40.12
PSB (B_2)	39.30	70.51	91.11	84.73	68	39.74
Azo + PSB (B_3)	42.86	76.46	99.53	93.51	75.10	43.36
S.Em±	0.68	1.85	2.27	2.51	1.58	0.85
C.D.5%	1.97	5.36	6.55	7.25	4.58	2.47

Table 2: Effect of fertility levels and liquid biofertilizers on yield of wheat

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Fertility levels (RDF)			
Control (F_0)	3038.96	5043.62	8082.58
75% RDF (F_1)	4596.62	6305.24	10901.86
100% RDF (F_2)	4917.51	6649.19	11566.7
125% RDF (F_3)	5073.97	6828.19	11902.16
S.Em±	96.819	137.708	186.634
C.D.5%	279.633	397.728	539.039
Biofertilizers			
No inoculation (B_0)	3072.09	5019.32	8091.41
Azotobacter (B_1)	4444.21	6136.38	10580.59
PSB (B_2)	4350.5	6036.55	10387.05
Azo + PSB (B_3)	5060.26	6801.00	11861.26
S.Em±	96.819	137.708	186.634
C.D.5%	279.633	397.728	539.039

Conclusion

On the basis of findings, the it is concluded that 100% RDF + *Azotobacter* + PSB in wheat found significant in term of growth, yield attributes and yield. So I recommend treatment 100% RDF + *Azotobacter* + PSB to increase the productivity of wheat to get maximum return from crop under the agro climatic condition of Sub-humid Southern Plain and Aravalli Hills of Rajasthan (Zone IVa).

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