Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)

xsgw¡ ¼*fV*ª*fVde ,LVhoe* ,y-½ dh mRikndrk ij moZjrk Lrjksa ,oa rjy tSo moZjdksa dk çHkko

HANSA KUMAWAT

Thesis

Master of Science in Agriculture

(Soil Science)

2021

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
RAJASTHAN COLLEGE OF AGRICULTURE

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
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Thesis

Submitted to the
Maharana Pratap University of Agriculture and Technology, Udaipur
In partial fulfillment of the requirements for the Degree of

Master of Science in Agriculture

(Soil Science)

By

HANSA KUMAWAT

2021

CERTIFICATE - I

CERTIFICATE OF ORIGINALITY

The research work embodied in this thesis titled **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)"** submitted for the award of degree of **Master of Science** in Agriculture in the subject of Soil Science to Maharana Pratap University of Agriculture and Technology, Udaipur (Raj.) is original and bonafide record of research work carried out by me under the supervision of **Dr. D.P. Singh,** Assistant Professor, Department of Soil Science and Agricultural Chemistry, Rajasthan College of Agriculture, Udaipur. The content of the thesis, either partially or fully, have not been submitted or will not be submitted to any other institute or University for the award of any degree or diploma.

The work embodied in the thesis represents my ideas in my words and where others ideas have been included; I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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This is to certify that the thesis entitled **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)"** submitted for the degree of **Master of Science** in Agriculture in the subject of **Soil Science,** embodies bona fide research work carried out by **Miss Hansa Kumawat** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 16/07/2021.

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This is to certify that **Miss Hansa Kumawat** student of **Master of Science in Agriculture, Department of Soil Science and Agricultural Chemistry**, Rajasthan College of Agriculture, Udaipur has made all corrections/ modifications in the thesis entitled **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)"** which were suggested by the external examiner and the advisory committee in the oral examination held on 06/09/2021. The final copies of the thesis duly bound and corrected were submitted on / /2021 are enclosed here with for approval.

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Date: 06/08/2021 **(Hansa Kumawat)**

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1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is most important staple food crop in the world. Wheat crop is cultivated over an area 17 per cent of crop acreage. Wheat crop sharing about 50 per cent calories in the human nutrition of our country. The chemical composition of wheat grain is 66-71.6% carbohydrates, 2.5-3.1% fats, 13-16.7% proteins and 2.5-3% crude fibre (Khan, 1984).There are different species of wheat out of which only three *Triticum* species are mostly cultivated all over the world. It is a self-pollinated crop originated from South West Asia.

Globally, wheat (*Triticum spp*.) is cultivated over an area 220 million hectare and having the highest acreage position among all crops, with annual production of around 781 million tonnes. 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). 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).

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). Nitrogen plays a most important role in biochemical and physiological functions of plants. It also increases process of photosynthesis, leaf area duration, leaf area production and net assimilation rate. It improves the food quality and enhances the crop yield (Leghari *et al.,* 2016). Nitrogen is responsible for dark-green colour in plants, stimulate leaves, stem and growth and development of other vegetative parts. Further, it promotes rapid early growth, improve fruit quality, stimulate the growth of leafy vegetables and enhance the protein content of fodder crop. It improves the uptake and utilization of potassium and phosphorous (Bloom, 2015 and Hemerly, 2016).

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 (Ziadi *et al*., 2008), it also increase photosynthetic activity and transport to the ripening grains (Hadis *et al*., 2018).Phosphorus increases the fixation of biological nitrogen and the consistency of

grain (Kumar *et al*., 2009). It is a constituent of energy rich compounds *viz.* adenosine triphosphate (ATP) and adenosine diphosphate (ADP), nicotinamide adenine dinucleotide phosphate (NADP), phytin, nucleic acid, phospholipids. Nitrogen and phosphorus uptake increased by application of phosphorus (Abdel-Aziz *et al*., 2018).

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 and Modi, 2012). Potassium increases drought tolerance and resistance to insect, pests, frost, lodging and diseases incidence (Wang *et al.,* 2013). The application of K fertilizers in wheat crop enhancing the k content in plant, dry matter, 1000-grain weight, protein contents, tillers, plant height and grain yield (Bahmanyar and Ranjbar, 2008). Potassium fertilizers also increased plant nutrition, crop quality and increased protein content (Wang *et al.,* 2003). N and P uptake significantly increases in straw and wheat grain through application of potassium fertilizers (Saifullah *et al.,* 2002).

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). 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 and Eissa*,* 2014). 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). 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).Biofertilizers have tremendous potential for supplying nutrient especially for nitrogen and Phosphorus. They are eco-friendly and low cost inputs and can reduce chemical fertilizer dose by 25-50% (Vance, 1997 and Rana *et al.,* 2012).

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). *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) 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).*Azotobacter vinelandii* produce azotobactin which protect the plant against soil borne phytopathoges (Husen, 2003).

Phosphate solubilizing bacterias (PSB) are beneficial micro-organisms which have the capacity to solubilise 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).Studies have shown that inoculation of PSB in soil or seed improves the capacity of plants to uptake and thereby enhance the use efficiency of applied chemical fertilizers (Panhwar *et al.,* 2014). Several researchers have reported that there is significant increase in yield of cereals through application of PSB (Ash-rafuzzaman *et al.,* 2009).

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).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).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).

Keeping in view the above facts, a field experiment entitled **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)"** will be conducted during *rabi*, 2019-20.

Objectives:

1. To study the effect of fertility levels and liquid biofertilizers on productivity of wheat.
2. To find out the effect of fertility levels and liquid biofertilizers on nutrient content and uptake by wheat.
3. To evaluate the effect of fertility levels and liquid biofertilizers on soil properties.

2. REVIEW OF LITERATURE

An attempt has been made in this chapter to present a brief review related to the research work done on **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)".** Due to lack of sufficient information on all aspects of liquid biofertilizers and fertility levels on wheat, related information on others crops has also been included.

2.1 EFFECT OF FERTILITY LEVELS

2.1.1 Growth, Yield Attributes and Yield

Laghari *et al.* (2010) carried out an experiment at Pakistan to evaluate the effect of different fertilizer regimes on growth, yield and nutrient uptake of various wheat cultivars. They revealed that no. of tillers, dry matter, grain yield, biological yield and harvest index significantly increases by the application of 100 per cent RDF (N: P: K-120: 60:60 kg ha^{-1}).

Malghani *et al.* (2010) conducted an experiment to examine the combined effect of NPK (Nitrogen, Phosphorus and Potash) on the growth and yield of wheat. They reported that application of 175-150-125 NPK kg ha^{-1} was found significant in grain yield (5168 kg ha^{-1}).

Dekhane *et al.* (2011) carried out a field experiment during 2008 at Junagadh. They revealed that highest grain yield (1441 kg ha^{-1}) and stover (1716 kg ha^{-1}) yield of cowpea significantly increased due to the application of 100% RDF and inoculation of *Rhizobium.*

An experiment was carried out by Abbasi *et al.* (2012) to investigate the effect of organic manures with recommended dose of NPK on the performance of wheat (*Triticum aestivum* L.) at Pakistan. They were observed that the maximum plant height and grain yield with the application 128-114-62 kg ha^{-1} NPK along with 6 t ha^{-1} poultry manure.

Agamy *et al.* (2012) conducted an experiment at Fayoum University (Egypt) to investigate the effect of the application of fertilizer on growth, yield, anatomical structure and some chemical components of wheat (*Triticum aestivum* L.) grown in newly reclaimed soil. They observed that the maximum plant height, test weight and grain yield with the application of biofertilizers + farmyard manure + 50% NPK.

Rai *et al.* (2013) conducted a field experiment during winter season of 2009-2010 at Kanpur. The results shown that grain and straw yield of barley significantly increases with the application of recommended dose of N:P:K:S:Zn (80:50:50:40:5 kg ha^{-1}) and farmyard manure 5 tonnes ha^{-1}.

Sarvade *et al.* (2014) concluded an experiment to assess the effect of spacing and fertility levels on growth and yield of wheat (*Triticum aestivum* L.) under different tree species in Terai region at Pantnagar during 2009-10. They observed that significant improvement in crop growth and yield were recorded with the application of 180-60-40 kg NPK ha^{-1}.

Samimi and Thomas (2016) conducted a field experiment at Allahabad during winter season to examine the effects of different levels of NPK on yield of wheat (*Triticum aestivum L.*). They found that application of (120-60-50) NPK kg ha^{-1} significantly increased in growth, maximum number of tillers per meter row length, grain yield, test weight and straw yield as compared to control.

An experiment was conducted by Indhumathi and Jeyamangalam (2017) at Tamil Nadu to evaluate the effect of different organic manures and their combinations on various physical properties of the soil and their impact on Pearl millet. The results indicate that highest grain yield 4953 kg ha^{-1} were recorded with the combinations of vermicompost + fertilizer.

Kakraliya *et al.* (2017) conducted a field experiment at C.S. Azad University of Agriculture and Technology, Kanpur to study the combined effect of organic and inorganic fertilizers on grain yield, fertilizer use efficiency and grain quality of wheat crop. The maximum grain yield (5.62 q ha^{-1}) and straw yield (7.53 q ha^{-1}) were recorded with the application of 125% RDF + vermicompost at 2.5 t ha^{-1} + FYM at 5 t ha^{-1} + *Azotobacter.*

Limanpure *et al.* (2017) conducted an experiment at Allahabad (U.P.) to find out the effect of different levels of inorganic fertilizers on the growth and yield of barley (*Hordeum vulgare)* under teak (*Tectona grandis*). They revealed that application of 65:50:50 kg NPK ha^{-1} significantly improve in plant height, No. of tillers, number of spikes, seed weight, grain yield, straw yield and harvest index.

Singh (2017) conducted an experiment during winter seasons of 2011-12 and 2012-13 at Agricultural Research Farm, R.B.S. College, Bichpuri (Agra). They observed that the 100% NPK fertilizers significantly increases the plant height, dry matter accumulation, effective tillers m^{-1}, test weight, grain (45.7q ha^{-1}) and straw (71.7q ha^{-1}) yield of barley over control. They also observed that grain (49.9 q ha^{-1}) and straw (87.4 q ha^{-1}) yield of barley which is obtain with the application of 75% NPK + 5 t FYM ha^{-1} + biofertilizers.

An experiment was conducted by Irfan *et al.* (2018) at Pakistan to assess the grain yield, nutrient accumulation and fertilizer efficiency in bread wheat under variable nitrogen and phosphorus regimes. They concluded that application 150-110 kg N-P_2O_5 ha^{-1} significantly enhanced plant height, number of tillers per plant, 100-grain weight and grain yield.

Jat *et al.* (2018) conducted a field experiment at Rajasthan College of Agriculture, Udaipur, during *kharif* and *rabi* season of the year 2010-2011 and 2011-2012 to evaluate the effect of integrated nutrient management on yield and nutrient uptake in sorghum-barley sequence. They observed that grain (45.14 and 23.43%) and stover (12.26 and 13.19%) yields both the crops increases with application of 100% NPK over the control.

Neelam *et al.* (2018) they revealed that the application of 100% RDN, which had significant effect on no. of effective tillers m-2 (413), grains per ear head (50.91) and 1000-grains weight (43.84 g). They further observed that highest grain yield (52.29 q ha^{-1}) and biological yield (124.50 q ha^{-1}) were recorded with application of 100% RDN.

Sial *et al.* (2018) conducted a field experiment at experimental farm of Nuclear Institute of Agriculture, Tando Jam to examine the effect of different P fertilizer rates and PSB on the growth and yield of wheat. They concluded that the application of 75 kg P_2O_5 ha^{-1} significantly improve the plant height (68.29 cm), grain yield (8.51 kg $plot^{-1}$) and seed index (3.77 g) over the control.

An experiment was carried out by Bhutada *et al.* (2019) and they observed that highest grain yield (3161 kg ha^{-1}) and fodder yield (7145 kg ha^{-1}) were obtained with the application of 100% RDF than control.

Verma *et al.* (2020) conducted an experiment at the SIF Farm of CSAUT, Kanpur during *Rabi* season of 2016-2017 to investigate effect of fertility levels and biofertilizers on root architecture, yield and nutrient uptake by crop. They revealed that higher yield of chickpea were obtain with combine application of 100% RDF along with Rhizobium + PSB + PGPR.

2.1.2 Nutrient Content and Uptake

Laghari *et al.* (2010) carried out an experiment at Pakistan to evaluate the effect of different fertilizer regimes on growth, yield and nutrient uptake of various wheat cultivars. They revealed that nitrogen, phosphorus and potassium uptake by wheat significantly increases with the application of 100% RDF (N: P: K-120: 60:60 kg ha^{-1}).

Dekhane *et al.* (2011) a field experiment carried out during 2008 at Junagadh. They revealed that highest nutrient content and uptake significantly increases by grain and stover of cowpea with the application of 100% RDF and inoculation of *Rhizobium.*

Rai *et al.* (2013) conducted a field experiment during winter season of 2009-2010 at Kanpur. The results shown that nitrogen and phosphorus uptake by barley increases with the application of recommended dose of N:P:K:S:Zn (80:50:50:40:5 kg ha^{-1}) and farmyard manure 5 tonnes ha^{-1}.

Paswan *et al.* (2014) conducted a field experiment at Agwanpur, Saharsa (Bihar) to studied effect of NPK uptake at different growth stages of wheat (*Triticum aestivum* L.). They found that maximum uptake of NPK by wheat were obtain with combination of chemical fertilizers and organic manure. The highest uptake of N and P reported with application 180 kg N ha^{-1} and 75 kg P_2O_5 ha^{-1}.

An experiment was conducted by Rakshit *et al.* (2015) at IARI, New Delhi, to evaluate the effect of super-optimal dose of NPK fertilizers on nutrient harvest index, uptake and soil fertility levels in wheat crop under a wheat-maize cropping system. They observed that application 200% RDF significantly enhanced content and uptake of nutrient in grain and straw of wheat.

Kakraliya *et al.* (2017) conducted a field experiment at C.S. Azad University of Agriculture and Technology, Kanpur to study the combined effect of organic and inorganic fertilizers on grain yield, fertilizer use efficiency and grain quality of wheat

crop. The maximum nitrogen uptake (116.11 kg ha^{-1}), phosphorus uptake (28.21 kg ha^{-1}) and potassium uptake (97.88 kg ha^{-1}) were recorded with the application of RDF + vermicompost at 2.5 t ha^{-1} + FYM at 5 t ha^{-1} + *Azotobacter*.

An experiment was conducted by Pepó and Karancsi (2017) at Institute of Crop Science, Hyderabad to examine the effect of fertilization on the NPK uptake of different maize (*Zea mays* L.) genotypes. They observed that application of high dose of NPK fertilizer gradually increases the uptake of NPK by wheat.

Reena *et al.* (2017) concluded a field experiment at Crop Research farm Nawabganj, Kanpur to determine the effect of each FYM, boron and sulphur with 100% recommended NPK ($N_{150}P_{60}K_{60}$) and their combine effect with 75% NPK of recommended NPK. They revealed that highest uptake of N, P, K, B and S were obtained with application of 75% NPK+S+B+FYM.

Singh (2017) an experiment carried out during winter seasons of 2011-12 and 2012-13 at Agricultural Research Farm, R.B.S. College, Bichpuri (Agra). They revealed that the application of 75% NPK + 5 t FYM ha^{-1} + biofertilizers enhanced the uptake of N, P and K by barley in grain and straw.

Jat *et al.* (2018) conducted a field experiment at Rajasthan College of Agriculture, Udaipur, during *kharif* and *rabi* season of the year 2010-2011 and 2011-2012 to evaluate the effect of integrated nutrient management on yield and nutrient uptake in sorghum-barley sequence. They observed that nitrogen, phosphorus and potassium uptake by sorghum (41.07, 29.13 and 21.10%) and by barley (31.98, 25.95 and 23.23%) were reported higher with the application of 100% NPK over control.

Pasley *et al.* (2019) they observed that the maximum uptake and content in grain and stover yield of maize were recorded with the application of nitrogen fertilizers. The application of 160 kg N ha^{-1} increases P, S, Cu and Zn uptake by maize over control.

Verma *et al.* (2020) conducted an experiment at the SIF Farm of CSAUT, Kanpur during *Rabi* season of 2016-2017 to investigate effect of fertility levels and biofertilizers on root architecture, yield and nutrient uptake by crop. They revealed that higher nutrient uptake by chickpea were obtain application of 100% RDF uptake by crop.

2.1.3 Soil properties

Liu *et al.* (2010) conducted an experiment to investigate the effect of long-term fertilizer and organic manure treatments on grain yield, soil chemical properties and some microbiological properties of arable soils in Pingliang, Gansu, China. The maximum microbial biomass carbon (MBC), microbial biomass nitrogen (MBN), soil dehydrogenase and alkaline phosphatases contents recorded with the application of inorganic fertilizers (nitrogen and phosphorus) along with organic manure.

An experiment was conducted by Katkar *et al.* (2011) at Akola, Maharashtra during 2007–08 to examine the effect of long-term fertilization and manuring on soil chemical and biological properties in vertisol. They observed that integrated application of organic manure (FYM @ 10 t ha^{-1}) and mineral fertilizer (100% NPK) significantly enhanced the available N, P, K and S. Further observed that maximum soil microbial biomass carbon, nitrogen and soil dehydrogenase obtain with same treatment.

Ali *et al.* (2015) carried out an experiment to investigate the effect of fertilizers on yield of maize-soybean intercrop and soil properties. The results revealed that application of NPK fertilizer significantly increases in total nitrogen status of the soil, available P, available K, soil pH and organic matter in soil after harvest of crop.

Brar *et al.* (2015) conducted an experiment to assess the effects of long-term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. They reported that maximum cumulative infiltration, infiltration rate, SOC pool (11.6 mg ha^{-1}) and aggregate MWD obtain with the application of 100%NPK + FYM.

Kundu *et al.* (2016) field experiment carried out at Barrackpore, West Bengal to determine the effect of applying organic and inorganic sources of nutrients on yield of jute-rice-wheat system and soil health. soil organic carbon (8.90 g kg^{-1}), available nitrogen (316 kg ha^{-1}), phosphorus (120 kg ha^{-1}) and potassium (236 kg ha^{-1}), microbial biomass (435 mg kg^{-1}) and alkaline phosphatase activity (479 to 616 µg $PNPg^{-1}$ h^{-1}) recorded with combined application of 100% NPK fertilizers and FYM.

Bhatt *et al.* (2017) conducted an experiment at Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, to evaluate the long-term effect of inorganic fertilizer and FYM on physico-chemical properties of soil under wheat-rice-wheat cropping system. The highest organic carbon (1.20 and 0.80%), available N (282.75 and 179.56 kg ha^{-1}) and P (28.31 and 12.72 kg ha^{-1}) recorded with the application of N_{180} +P_{80} +K_{40} +Zn (fertilizers) + FYM.

An experiment was carried out by Phullan *et al.* (2017) to study the effect of organic manure and mineral fertilizers on wheat growth and soil properties. They observed that the application of mineral fertilizer (120-90 kg N-P_2O_5 ha^{-1}) along with FYM (6 t ha^{-1}) significantly increases in organic matter (51%) content and decreases in bulk density (13%).

Sial *et al.* (2018) conducted a field experiment at experimental farm of Nuclear Institute of Agriculture, Tando Jam to examine the effect of different P fertilizer rates and PSB on the growth and yield of wheat. They concluded that the application of 75 kg P_2O_5 ha^{-1} improve the bacterial count after harvest of wheat crop.

Verma *et al.* (2019) conducted an experiment at the SIF Farm of CSAUT, Kanpur during *Rabi* season of 2016-2017 to investigate effect of fertility levels and biofertilizers on the chemical and biological properties of soil under late sown chickpea (*Cicer arietinum* L.). They revealed that the chemical properties, microbial populations and enzymatic activity significantly batter after harvest of chick pea with the application of 100% RDF.

Adekiya *et al.* (2020) conducted an experiment at Nigeria during 2014 and they revealed that application of urea fertilizers in three split application (60 ` + ` 30 + 30) with 8 ` *t* ` ha^{-1} poultry manure recorded highest values of soil chemical properties such as pH, OM, N, P and K.

2.2 EFFECT OF LIQUID BIOFERTILIZES

2.2.1 Growth, yield attribute and yield

An experiment was conducted by Katiyar *et al.* (2011) to determine the effect of *Azotobacter* and nitrogen levels on yield of wheat. They were observed that seed inoculated with *Azotobacter* enhanced the grain yield up to 1.92-2.0% as compared to non-inoculated seed.

Singh and Prasad (2011) reported that combine application of biofertilizers responsible for significant improvement in plant height and tillering. They also reported that the yield component of wheat *i.e.* grain ear^{-1}, test weight and grain yield enhanced with the application of biofertilizers either alone or in combination.

Yousefi and Barzegar *et al.* (2014) revealed that inoculation of biofertilizers (*Azotobacter and Pseudomonas*) with chemical fertilizers significantly improve the plant height, 1000 grain weight, grain yield, biological yield and harvest index of wheat. Combined use of biofertilizers (*Azotobacter* and Pseudomonas) and fertilizers reduced chemical fertilization about 25-50% in the field.

Khandare *et al.* (2015) conducted an experiment at Pantnagar to assess the effects of varying rates and methods of application of carrier based and liquid *Azotobacter* and PSB biofertilizers in combination with chemical fertilizers in wheat (*Triticum aestivum* L.). They revealed that application of 0.625 L ha^{-1} liquid biofertilizers in soil with 75% N P significantly improve in plant growth, straw yield, grain yield, total tillers, effective tillers and 1000 grain weight.

Singh *et al.* (2015) reported that maximum plant growth parameter, yield attributing characteristics, grain yield (1.23 kg ha^{-1}) were obtain with combine application of *Azotobacter* spp. and *Azospirillum* spp.

Obid *et al.* (2016) conducted an experiment during two successive winter seasons of 2011/2012 and 2012/2013 at Sudan University of Science and Technology, College of Agricultural Studies, the Demonstration Farm, Shambat, to investigate the effect of bio-fertilizer (Effective Microorganisms, EM) on maize (*Zea mays* L.). They observed that the application of liquid biofertilizers at the rate 18.75 L ha^{-1} significantly increases in plant height, 100- grain weight and grain yield of maize.

Gautam *et al.* (2017) carried out an experiment at Instructional Farm, Rajasthan College of Agriculture, Udaipur to examine the effect of carrier based and liquid biofertilizers at different phosphorus levels in hybrid maize during *kharif* season of 2016. They observed that maximum grain cob^{-1}(307.33), grain weight plant^{-1}(68.52 g), cob girth (16.52 cm), cob length (22.95 cm), shelling (79.27%) and test weight (202.59 g) were recorded with the combine application of LBF1+CB+60 kg P_2O_5 ha^{-1}. They also observed that seed yield, stover yield, biological yield and harvest index significantly improve with the application of LBF1+CB+60 kg P_2O_5ha^{-1}.

Mecarty *et al.* (2017) conducted an experiment at Allahabad (U.P.) to study the effect of *Azotobacter* and phosphobacteria on yield of wheat (*Triticum aestivum*) during *Rabi* season of 2011-12. They revealed that the seed treatment with liquid PSB and *Azotobacter* give maximum number of tillers plant^{-1}, plant height, grain yield and straw yield.

Kaur *et al.* (2018) conducted an experiment at Research Farm of the Department of Agriculture, Fatehgarh Sahib during *rabi* season of 2017 to examine the effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.) under irrigated conditions. They observed that highest plant height (cm) and numbers of tillers obtain with application of 75% NPK + vermicompost @ 2.5 t ha^{-1} + *Azotobacter.*

Mahato and Kafle (2018) carried out an experiment at Nepal during the winter season of 2016–17. Maximum plant height, grain weight, total biomass, grain yield and biological yield were significantly obtained with the application of *Azotobacter* + 120:80:80 kg NPK ha^{-1} + 10 t FYM ha^{-1}.

An experiment was conducted by Sivamurugan *et al.* (2018) during *kharif*, 2016 at Tamil Nadu Agricultural University, Coimbatore in sandy clay loam soil to evaluate the effect of different levels of p with varied liquid biofertilizers on growth, yield attributes and yield of maize. The results shown that application of 60 P_2O_5 kg ha^{-1} + NPK consortia (liquid biofertilizers) significantly improve the grain yield (5308 kg ha^{-1}).

Deshpande (2019) carried out an experiment and they reported that maximum growth parameter such as plant height, root length, root nodulation, leaf area and chlorophyll content were found with the application of 125% RDF + Rhizobium + PSB. They also observed that highest seed and straw yield were obtained with same treatment.

Kumar *et al.* (2019) carried out an experiment and reported that the application of biofertilizers (PSB and AM) along with 60 kg P_2O_5 ha^{-1} had significant effect on yield, dry matter accumulation, fresh and dry weight of nodule of chickpea.

An experiment was carried out by Gao *et al.* (2020) and they concluded that application of the biofertilizers mixture (*Azotobacter chrocoocum*, AMF and *Bacillus circulans*) along with organic fertilizers enhanced growth and yield of maize crop.

Mohanta *et al.* (2020) conducted an experiment during *Rabi* season of 2011-12 at Sriniketan (West Bengal). They observed that maximum plant height, yield attributes and yield obtain with the combine application of 125% RDF and *Azotobacter* +PSB.

An experiment conducted by Purwani and Nurjaya (2020) at Bogor Regency to study the effect of inorganic fertilizer and biofertilizers application on maize yield and fertilizer use efficiency. The results revealed that the maximum shoot dry weight (138.09 g pot^{-1}) and corn yield (90.87 g pot^{-1}) were reported with the combine application of NPK (50% recommended dose) +biofertilizers(4 L ha^{-1}).

2.2.2 Nutrient content and uptake

An experiment conducted by Bahadur *et al.* (2013) and they revealed that maximum NPK uptake by wheat were reported with application of 125 % RDF and 100% RDF + 5 t ha^{-1} FYM along with PSB + *Azotobacter*.

Minaxi *et al.* (2013) conducted a field experiment and reported that application of *Azotobactor* + PSB amended with AM (*G. etunicatum*) + tri calcium phosphate recorded maximum increase in N (145%) and P (171%) content than control.

Sarker *et al.* (2014) revealed that nutrient contents (%N, %P and %K) in plant tissue significantly improve with the application of phosphate solubilizing bacteria (PSB).

Khandare *et al.* (2015) conducted an experiment at Pantnagar to investigate the effects of varying rates and methods of application of carrier based and liquid *Azotobacter* and PSB biofertilizers in combination with chemical fertilizers in wheat (*Triticum aestivum* L.). They observed that the application of 0.625 L ha^{-1} liquid biofertilizers in soil with 75% NP significantly enhanced the uptake of NPK by wheat.

An experiment was conducted by Dahiphale *et al.* (2017) to examine the effect of liquid and carrier based bioinoculants on content and uptake of NPK for sunflower at College of Agriculture, Badnapur, Parbhani-India. Their results revealed that highest content and uptake of NPK by sunflower were obtained with combined application of liquid *Azotobacter* and PSB.

Raja and Takankhar (2018) conducted an experiment at Maharashtra during *kharif* season of 2013-14. They observed that seed treatment with liquid Bradyrhizobium (10 ml) and liquid PSB (10 ml) significantly improve the nitrogen content (at maturity 7.93% and 3.62% at harvest) and Phosphorus content (at maturity 28.57% and at harvest 31.25%) over control.

Deshpande (2019) carried out an experiment and they reported that maximum nutrient uptake by cowpea were found with the application of 125% RDF + Rhizobium + PSB.

An experiment was carried out by Goa *et al.* (2020) and they concluded that application of the biofertilizers mixture (*Azotobacter chrocoocum*, AMF and *Bacillus circulans*) along with organic fertilizers enhanced nutrient uptake by maize.

Jalal *et al.* (2020) they revealed that application of beneficial microorganisms (*Azotobacter chroococcum and Azospirillum brasilense*) with 100% organic source and inorganic nitrogen significantly increases in nitrogen content in grain and stover of maize.

Mohanta *et al.* (2020) conducted an experiment during *Rabi* season of 2011-12 at Sriniketan (West Bengal). They observed that maximum nutrient uptake by wheat were obtain with the combine application of 125% RDF and *Azotobacter* +PSB.

2.2.3 Soil properties

Kaur and Reddy (2014) conducted an experiment to evaluate the effect of PSB (*Pantoeacy pripedia* and *Psedomonas placoglossicida*) inoculation on soil biological properties and revealed that significantly improvement in acid phosphates, alkaline phosphate and dehydrogenase enzyme activities after harvest of wheat were reported with inoculation of both PSB.

Parewa *et al.* (2014) an experiment carried out at Banaras Hindu University, Varanasi (U.P.) during *rabi* seasons of 2009-10 and 2010-11 result revealed that combine application of inorganic fertilizers with FYM and bioinoculants significantly improve the dehydrogenase, phosphatase enzyme activity, soil microbial biomass carbon (SMBC), microbial population of soil, available N, P and K after harvest of wheat crop.

Singh *et al.* (2015) conducted a field experiment during two consecutive *rabi* seasons of 2012 and 2013 at Research Farm, ICAR Sikkim Centre, Tadong to examine the effect of different microbial inoculants on selected soil biological properties. The results shown that soil biological properties effectively increased due to seed inoculation with biofertilizers. Resulted in highest soil microbial biomass carbon (SMBC) and dehydrogenase activities at all the growth stages of common buckwheat were obtain with combine application of *Azotobacter* spp. and *Azospirillum* spp.

Singh *et al.* (2015) revealed that application of vermicompost + crop residues and biofertilizers enhanced the organic carbon (0.64%) and soil microbial biomass (103.8 µg g^{-1}).

An experiment carried out by Jangir *et al.* (2017) during *kharif,* 2014 at Instructional Farm, Rajasthan College of Agriculture, Udaipur, (Rajasthan). They observed that organic carbon, available N, P_2O_5, K_2O, Zn, Cu, Mn and Fe content in soil significantly improve with application of 100% RDF and seed inoculation with *Rhizobium* + PSB.

An experiment carried out by Brar *et al.* (2017) to determine the effect of different sources of nutrition on microbial dynamics and soil enzymatic activities in maize crop. They observed that bacterial population (285.10×10^8cfu g^{-1} soil), fungal population (89.70×10^4 cfu g^{-1} soil), P-solubilizers population (240×10^3cfu g^{-1} soil) and soil alkaline phosphatase activity (28.6 mg PNP g^{-1}soil hr^{-1}) was found significantly higher with application of FYM + non-edible oil cakes + biofertilizers. However diazotrophic population (27.96×10^6cfu g^{-1} soil), urease activity (615µg g^{-1} soil hr^{-1}), actinomycetes population (76.17×10^4cfu g^{-1} soil) and dehydrogenase activity (475 µg TPF g^{-1}soil hr^{-1}) was found significantly highest with combine application of 50% N as FYM + biofertilizers.

Goyal *et al.* (2017) conducted an experiment to study the "Effect of organic, inorganic, bio-fertilizer and seed inoculation on soil properties, growth and yield of maize (*Zea may* L.) Var. hybrid MM-2255" on Crop Research Farm Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Allahabad during *kharif* season 2016-17. They observed that improvement in soil fertility status significantly increased with the application 100% nitrogen ha^{-1}+100% FYM and *Azotobacter*. The combine application of Nitrogen, FYM and *Azotobacter* resulted in

a little improve in pH 7.50, EC 0.36 dSm^{-1}, particle density 2.85g/cc, organic carbon 0.73%, bulk density 1.30g/cc, water holding capacity 51.32%, pore space 55.91% and available N 330.5 kg ha^{-1}, available P 32.76 kg ha^{-1}, available K 212.88 kg ha^{-1}.

Namli *et al.* (2017) conducted a field experiment to examine the effect of PSB on plant growth, soil biological properties including enzymes and soil respiration at Turkey. The results shown that in rhizosphere soil pH significantly increased and in bulk soil pH decreased with PGPR treatments. Further they reported that alkaline phosphatase, β glucosidase activities, quantity of N, P and organic matter was found significantly higher with PGPR treatment.

Verma *et al.* (2019) conducted an experiment at the SIF Farm of CSAUT, Kanpur during *Rabi* season of 2016-2017 to investigate effect of fertility levels and biofertilizers on the chemical and biological properties of soil under late sown chickpea (*Cicer arietinum* L.). They revealed that chemical properties, microbial populations and enzymatic activity after harvest of chick pea significantly batter with the application of Rhizobium + PSB + PGPR.

An experiment was carried out by Gao *et al.* (2020) and they concluded that application of the biofertilizers mixture (*Azotobacter chrocoocum*, AMF and *Bacillus circulans*) along with organic fertilizers enhanced acid phosphatase, dehydrogenase enzymes and bacterial count in soil after harvest of maize.

Jalal *et al.* (2020) they revealed that application of beneficial microorganisms (*Azotobacter chroococcum and Azospirillum brasilense*) with 100% organic source significantly increases in soil organic matter, soil total nitrogen and significantly decreases in soil bulk density.

3. MATERIALS AND METHODS

A field experiment entitled **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity ofWheat (*Triticum aestivum* L.)"** was laid during *rabi* season of 2019-20. The details of experimental methods, materials used and criteria followed for the treatment evaluation during the course of investigation are provided under relevant headings in this section.

3.1 EXPERIMENTAL SITE

The experiment was carried out at the Agronomy Instructional Farm, Rajasthan Collegeof Agriculture, MPUAT, Udaipur. The site was situated at 24°35' N latitude, 73°42' E longitude and an altitude of 582.17 metres 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).

3.2 CLIMATE AND WEATHER CONDITION

This zone possesses typical subtropical climatic conditions characterized by pleasant winters and moderate summer associated with high relative humidity during the months of July to September. The mean annual rainfall of this region is 601 mm, most of which is contributed by south-west monsoon from July to September. Rainfall received during cropping period was 42.6 mm.

The mean weekly meteorological observations recoded at Agro-meteorological observatory, Rajasthan College of Agriculture, Udaipur during cropping period are presented in Table 3.2 and Fig. 3.1. The wheat crop experienced maximum and minimum temperature ranged between 37.3°C and 20.8°C, respectively.Mean weekly maximum and minimum relative humidity ranged between 86.7and 16.7 per cent, respectively. Total rainfall and maximum evaporation were 42.6 and 9.9 mm was recorded during crop season.

3.3 PHYSICO-CHEMICAL PROPERTIES OF EXPERIMENTAL SOIL

In order to ascertain physico-chemical characteristics of the experimental field, soil samples up to 15 cm depth were collected randomly from different spot of investigation site and a composite sample was prepared by mixing the soil. The composite soil sample for the different mechanical, physical and chemical properties

of the experimental soil was analysed using standard methods. The results of the soil analysis are presented in Table 3.1 along with the methods used for the above-mentioned determinants. The soil texture of the experimental field was clay loam, slightly alkaline in reaction, low in available nitrogen, medium in available phosphorus and high in available potassium.

Table 3.1: Initial soil properties of experimental soil

Properties	value
Sand (%)	38.47
Silt (%)	26.46
Clay (%)	34.57
Textural class	Clay loam
Bulk density (Mg m^{-3})	1.44
Particle density (Mg m^{-3})	2.48
Porosity (%)	41.93
Chemical analysis	
pH (1:2, soil : water)	8.25
EC (dSm^{-1}) (1:2, soil: water)	0.82
Organic carbon (%)	0.56
Available nitrogen (kg ha^{1})	253.80
Available phosphorus (kg ha^{-1})	20.09
Available potassium (kg ha^{-1})	380.03
Available sulphur (mg kg^{-1})	8.12
Available Zn (mg kg^{-1})	0.59
Available Fe (mg kg^{-1})	4.04
Available Mn (mg kg^{-1})	7.32
Available Cu (mg kg^{-1})	1.46
Soil microbial biomass carbon (mg kg^{-1})	159
Soil microbial biomass nitrogen (mg kg^{-1})	23.76
Dehydrogenase activity (µg TPF g^{-1} soil h^{-1})	8.70
Alkaline phosphatase activity (µg P-nitrophenol released g^{-1}soil ha^{-1})	14.52

3.4 CROPPING HISTORY OF THE EXPERIMENTAL SITE

The cropping history of the experimental fields for the last three years is given in table 3.3.

Table 3.3: Previous history of experimental field

Year	*Kharif*	*Rabi*
2017-2018	Sorghum	Wheat
2018-2019	Maize	Wheat
2019-2020	Cowpea	Wheat*

* Experimental crop

3.5 EXPERIMENTAL DETAILS

The experiment was laid out in factorial randomized block design with three replications during *rabi* 2019-20. The experiment consisting of sixteen treatments were assigned randomly to different trial units. The plan of the experimental site with treatment allocation and other experimental site - related information is presented in Fig. 3.2.

3.5.1 Treatment Details

The experiment consisted of sixteen treatments as shown in Table 3.4.

Table 3.4: Details of the treatments with their symbols

Treatment details
A. Fertility levels
F_0: Control
F_1: 75% RDF*
F_2: 100% RDF
F_3: 125% RDF
B. Biofertilizers inoculation
B_0: Control
B_1: Liquid *Azotobacter*
B_2: Liquid PSB
B_3: Liquid *Azotobacter* + PSB

***** RDF-Recommended dose of fertilizer (N–120, P_2O_5–60 and K_2O–40 kg ha^{-1})

Table 3.5: Details of the different treatment combination with their symbols

Treatment	Symbol	Treatment Combination
T_1	F_0B_0	Control
T_2	F_0B_1	C + *Azo*
T_3	F_0B_2	C + PSB
T_4	F_0B_3	C + *Azo* + PSB
T_5	F_1B_0	75% RDF
T_6	F_1B_1	75% RDF + *Azo*
T_7	F_1B_2	75% RDF + PSB
T_8	F_1B_3	75% RDF + *Azo* + PSB
T_9	F_2B_0	100% RDF
T_{10}	F_2B_1	100% RDF + *Azo*
T_{11}	F_2B_2	100% RDF + PSB
T_{12}	F_2B_3	100% RDF + *Azo* + PSB
T_{13}	F_3B_0	125% RDF
T_{14}	F_3B_1	125% RDF + *Azo*
T_{15}	F_3B_2	125% RDF + PSB
T_{16}	F_3B_3	125% RDF + *Azo* + PSB

3.5.2 Other Experimental Details

Table 3.6: Other experimental details

S. No.	Particulars		Details
1.	Season	:	*Rabi*, 2019-20
2.	Variety	:	Raj-4238
3.	Seed rate	:	125 kg ha^{-1}
4.	Experimental design	:	Factorial RBD
5.	Number of treatments	:	16
6.	Number of replications	:	3
7.	Total number of plots	:	48
8.	Spacing (Row to row)	:	22.5 cm
9.	Plot size		
	a. Gross plot size	:	5 m × 3 m = 15 m^2
	b. Net plot size	:	4.5 m × 2.5 m = 11.25 m^2
10.	Nutrient management	:	As per treatments

3.6 SOURCES OF FERTILIZERS AND LIQUID BIOFERTILIZERS

3.6.1 Source of Fertilizers

The fertilizers urea, DAP and MOP was obtain from the Agronomy Farm,Rajasthan college of Agriculture, Udaipur.The half dose of nitrogen and full dose of phosphorus and potassium fertilizers were used as basal dose and remaining half dose of nitrogen were given in two equal splits with 1st and 3rd irrigation respectively.

3.6.2 Source of Liquid Biofertilizers

The liquid based *Azotobacter chroococcum* and PSB (*Bacillus megatherium*) biofertilizers was obtained from Department of Molecular Biology and Biotechnology, Rajasthan college of Agriculture, Udaipur. Biofertilizers were used as seed inoculation at the time of sowing as per treatment.

3.7 DETAILS OF CROP RASING

The schedule of different pre and post sowing operations carried out during *Rabi* season are given in Table 3.7 and details of crop raising is described as under.

Table 3.7: Calendar of field operations during crop growth period

S. No.	Operations		Date	Particulars
1.	Ploughing and field preparations		16-12-2019	By tractor drawn disc harrow and rotavator
2.	Layout and seed bed preparation		17-12-2019	Manually
3.	Furrow opening		18-12-2019	Manually
4.	Fertilizer placement		18-12-2019	Manually
5.	Sowing		18-12-2019	Manually
6.	Irrigation	i.	18-12-2019	With check basin method
		ii.	08-01-2020	
		iii.	29-01-2020	
		iv.	23-02-2020	
		v.	20-03-2020	
		vi.	16-04-2020	
7.	Weed control		21-01-2020	Spraying of weedicides with knapsack sprayer
8.	Harvesting		25-04-2020	Hand harvested from net plot size
9.	Threshing and winnowing		29-04-2020	Threshed with power operated thresher and cleaned with winnowing fan

3.7.1 Field Preparation

After harvesting of *kharif* cowpea, the experimental field was ploughed with the help of tractor drawn disc plough and cross harrowing later on with rotavator to bring the soil in to good tilth. The crop stubbles, weeds and grasses were detached from field manually. There after the experimental field was marked into different plots as per details given in Fig. 3.2.

3.7.2 Sowing

Before sowing, wheat seed were first inoculated with liquid biofertilizers as per treatment. Furrows were opened in each plot at a row distance of 22.5 cm with the help of kudali. The seeds of wheat variety Raj-4238 was sown in furrows using seed rate of 125 kg ha^{-1}on18th December 2019.The seeds sown in furrows were covered with a thin layer of soil for uniform germination and to protect from bird damage after that water was given.

3.7.3 Treatment Application

(i) Fertilizers: As per treatment required dose of nitrogen by subtracting the amount of N supplied through DAP and remaining by urea, P_2O_5through DAP and K_2O through MOP was applied to the crop. At the time of sowing, half dose of nitrogen and full dose of phosphorus, potassium was applied before the sowing and remaining half dose of nitrogen was applied in two equal splits during 1st and 3rd irrigation.

(ii) Liquid biofertilizers: A plastic bag used for the seed treatment. The bag filled with 1 kg of seeds and required amount of biofertilizers (@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.

3.7.4 Thinning and Weeding

In order to maintain optimum intra row spacing thinning was done at 20 DAS. For keeping field weed free spray of post emergence herbicide at 35 DAS (2, 4-D *a.i.* 0.5 kg ha^{-1}).

3.7.5 Harvesting

The crop was harvested at full maturity on 25 April 2020 from border area were harvested separately and removed from each plot. The plot of net area was harvested and wrapped in bundles, tagged and placed on the threshing floor to drying. After proper drying these bundles were weighed just before threshing to record treatment wise biological yield.

3.7.6 Threshing and winnowing

Threshing of the harvested crop on 29 April 2020 from each plot was done with the help of power operated thresher. Seeds were winnowed, cleaned and sundried and weighed separately to record seed yield of individual plot.

3.8 TREATMENT EVALUATION

In order to evaluate the effect of treatment on growth, yield attributing characters and yield, nutrient content, their uptake and other aspects of wheat crop, observations were recorded for each parameter as per method mentioned below.

3.8.1 Growth Attributes

3.8.1.1 Plant height

Plant height was recorded at 30 DAS, 60 DAS and at harvest on the basis of five randomly selected plants. From each plot the plant height was measured from the ground level to the fully opened uppermost leaf tip with the help of metre scale and the mean plant height was worked out and expressed in cm.

3.8.1.2 Number of total tillers metre^{-1} row length

Number of total tillers was counted non-destructively from two randomly selected one metre row length in each plot. The mean number of total tillers m^{-1} row length was work out in each treatment.

3.8.1.3 Number of effective tillers metre^{-1} row length

Number of effective tillers (ear bearing tillers) were counted from randomly selected two rows from one-metre row length and averaged.

3.8.2 Yield and Yield Attributes

3.8.2.1 Test weight

A sample drawn from the finally winnowed and cleaned produce of each plot after weighing, there after 1000 grains were counted and weighed on electronic balance and expressed in gram.

3.8.2.2 Grain yield

The total grain yield of net plot was threshed, winnowed, cleaned, dried and weighed, seed yield was worked out and expressed in kg ha^{-1}.

3.8.2.3 Straw yield

The straw yield was calculated by subtracting the corresponding grain yield from respective biological yield recordedper plot and expressed in kg ha^{-1}.

3.8.2.4 Biological yield

The harvested bundles of each net plot were sun dried for one week and weighed for recording biological yield in kg ha^{-1}.

3.8.2.5 Harvest index

The ratio of economic yield (grain yield) to biological yield was worked out by following formula and expressed in percentage as suggested by Donald and Hamblin (1976).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.8.3 Chemical Analysis of Plant Sample

Table 3.8: Methods followed for plant analysis

Sr. No.	Determination	Method used	Reference
1.	Nitrogen digestion with H_2SO_4-H_2O_2	Nessler's reagent, spectrophotometrically	Snell and Snell (1949)
2.	Phosphorus digestion with di-acid HNO_3 : $HClO_4$ (10 :4)	Vanadomolybdate phosphoric acid yellow colour method	Jackson (1973)
3.	Potassium	Flame photometer method	Jackson (1973)
4.	Iron, Zinc, Copper and Manganese	Atomic absorption spectrophotometrically	Lindsay and Norvell (1978)

3.8.3.1 Nutrient content and uptake

For the analysis of N, P, K, S, Zn, Mn, Cu and Fe in the samples of grain and straw was taken during threshing of harvested wheat crop which was oven dried and then grinded by electrical grinder machine stainless steel Willey mill. Nutrient content in grain and straw were analysed by using standard methods as per given in Table 3.8. The uptake of macronutrients (N, P, K and S) was expressed inkg ha^{-1}, while their content in per cent. In the case of micronutrients (Zn, Mn, Cu and Fe) content was expressed in mg kg^{-1} or ppm, while their uptake expressed in g ha^{-1}.

Uptake of macro and micro nutrients were calculated from the data of the macro and micro nutrients content in grain and straw by using the following formula:

For macronutrients

$$\text{Nutrient Uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg ha}^{-1})}{100}$$

For micronutrients

$$\text{Nutrient Uptake (g ha}^{-1}) = \frac{\text{Nutrient content (mg kg}^{-1}) \times \text{Yield (kg ha}^{-1})}{1000}$$

3.8.4 Soil Analysis

3.8.4.1 Soil properties

To determine the fertility status of soil, the undisturbed soil samples was randomly collected from every experimental unit with the help of auger from 0-15 cm depth after harvesting of wheat crop. These soil samples were dried and passed through a 2.0 mm sieve to prevent metallic uncleanness.The parameters of soil *i.e.* pH, EC, organic carbon, bulk density, particle density and available N, P, K, S, Zn, Mn, Cu and Fewere analysed by using standard methods of analysis given in Table 3.9.

3.8.4.2 Soil biological properties

The estimation of microbial population was done by standard serial dilution and plate count method (Scmidt and Colwell, 1967). The choroform-fumigated incubation method was used for microbial biomass carbon analysis (Vance *et al.*, 1987) and chloroform fumigation method was used for microbial biomass nitrogen (Shen *et al.*, 1984). Soil acid and alkaline phosphatase activities were examine by β nitrophenol phosphate by spectrophotometry method (Tabatabai and Bremner, 1969). An Anthrone extraction method used for analysis of soil dehydrogenase activity (Casida *et al*. 1964).

Table 3.9: Methods followed for soil analysis

S. No.	Properties	Procedure	Reference
1.	pH (1:2 soil water suspension)	Potentiometeric method using pH meter	Richards (1954)
2.	EC (1:2 soil water suspension)	Using solubridge method (Conductivity meter)	Richards (1954)
3.	Organic carbon (%)	Rapid titration method	Walkley and Black (1934)
4.	Bulk Density	Core sampler method	Singh (1980)
5.	Particle density (P.D.)	Relative density bottles method, USDA, Hand book No. 60	Richards (1954)
6.	Porosity	Calculated by using the formula USDA, Hand book No. 60 $\text{Porosity (\%)} = \frac{PD - BD}{PD} \times 100$	Richards (1954)
7.	Available nitrogen	By alkaline permanganate method	Subbiah and Asija (1956)
8.	Available Phosphorus	Extraction of soil with 0.5 M $NaHCO_3$ at pH 8.5 and development of blue colour with $SnCl_2$ and measurement through colorimetrically	Olsen *et al.* (1954)
9.	Available potassium	Extraction with 1 N neutral ammonium acetate at pH 7.0 and determined by flame photometer	Merwin and Peech (1951)
10.	Available Zn, Fe, Cu & Mn	Extraction by 0.005 M DTPA + 0.001M $CaCl_2$ + 0.1M triethanolamine at pH 7.3	Lindsay and Norvell (1978)
11.	Micronutrient fraction	Sequential fraction analysis method	Jackson (1979), Viet (1962)
12.	Microbial population	Standard serial dilution and plate count method	Scmidt and Colwell (1967)
13.	Soil microbial biomass carbon	Chloroform fumigation-extraction method	Vance *et al.* (1987)
14.	Soil microbial biomass nitrogen	Chloroform fumigation method	Shen *et al.* (1984)
15.	Dehydrogenase activity	Colorimetric determination of TPF	Casida *et al.* (1964)
16.	Alkaline phosphatase activity	Spectrophotometry method	Tabatabai and Bremner (1969)

3.9 ECONOMICS ANALYSIS

3.9.1 Net Returns (` ha^{-1})

To ascertain the profitability of different treatment, economics was worked out in terms of net returns (` ha^{-1}) computed through subtracting cost of treatment and cost of cultivation from gross income gained. Prevalent prices of yield and inputs labour rates were used to computing the cost of cultivation and net profit.

3.9.2 Benefit-cost Ratio

BC ratio was calculated to evaluate treatment efficacy and productivity by using following formula:

$$\text{BC ratio} = \frac{\text{Net return (` ha}^{-1}\text{)}}{\text{Total cost of cultivation (` ha}^{-1}\text{)}}$$

3.10 STATISTICAL ANALYSIS

The experimental data were subjected to statistically analysis of variance by the procedure appropriate to the experiment carried out in factorial RBD as defined by Panse and Sukhatme (1985). Explanation of results was based on 'F' test. The comparison between means was made by calculating critical difference (CD) at 5% level of significance. Summary tables along with SEm± and CD (p=0.05) have been prepared and are given in the text of the chapter entitled "Experimental Results" and their analysis of variance for different parameters are given in the appendices at the end.

4. EXPERIMENTAL RESULTS

Results of the field experiment entitled **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)"** conducted during *rabi* season of 2019-20 at Instructional Farm, Rajasthan College of Agriculture, Udaipur situated in the Sub-humid Southern Plain and Aravalli Hills of Rajasthan (Zone IVa) are being presented in this chapter. Data pertaining to effect of treatments on growth, yield attributes, yield, nutrient concentration in plant and their uptake and in soil after crop harvest were analyzed statistically using standard methods to test their significance and the analysis of variance for these data have been presented in Appendices at the end. Results of the main effects and interactions have been presented and illustrated graphically wherever felt essential for better understanding.

4.1 GROWTH PARAMETERS, YIELD ATTRIBUTING AND YIELD

The data regarding the effect of application of fertility levels and inoculation of liquid biofertilizers on plant height, number of total tillers m^{-1} row length, effective tillers m^{-1} row length, test weight of wheat are being summarized in Table 4.1 to 4.5 and analysis of variance given in Appendices I-V.

4.1.1 Plant Height

Effect of fertility levels

Data presented in Table 4.1 and Fig. 4.1 show that plant height at 30 DAS, 60 DAS and at harvest of wheat was significantly affected as compared to control due to application of different fertility levels during *rabi* season of 2019-20.

At 30 days after sowing, the plant height was significantly increased to each higher level of fertility up to 100% RDF (44.10 cm) but it remained at par with 125% RDF (44.90 cm). The data further revealed that the per cent increase in plant height was in order of 19.00, 26.00 and 28.65 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

At 60 days after sowing, the plant height was significantly increased to each higher level of fertility up to 100% RDF (77.49 cm) but it remained at par with 125% RDF (79.30 cm). The data further revealed that the per cent increase in plant height was in order of 15.18, 24.50 and 27.41 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

At harvest, the plant height was significantly increased to each higher level of fertility up to 100% RDF (100.91cm) but it remained at par with 125% RDF (102.30 cm). The data further revealed that the per cent increase in plant height was in order of 11.79, 19.81 and 21.46 due to application of 75 % RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is evinced from data (Table 4.1and Fig. 4.1) that plant height at 30 DAS, 60 DAS and harvest was significantly affected due to inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB as compared to control.

At 30 days after sowing, the maximum plant height (42.86 cm) was recorded with the inoculation of *Azotobacter* + PSB (B_3) and minimum plant height (34.89 cm) was observed with no inoculation (B_0). Whereas treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The plant height was increased by 17.65, 12.63 and 22.84per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

At 60 days after sowing, the highest plant height (76.46 cm) was observed with inoculation of *Azotobacter* + PSB (B_3) and minimum plant height (63.22 cm) was found with no inoculation (B_0). Whereas treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The plant height was increased by 13.39, 11.53 and 20.94 per cent due to application of *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

At harvest, the maximum plant height (99.53 cm) was recorded with inoculation of *Azotobacter* + PSB (B_3) and minimum plant height (86.72 cm) was found with no inoculation (B_0). Whereas treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The plant height was increased by 7.47, 5.06 and 14.77 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.1.2 Number of Total Tillers m^{-1} Row Length

Effect of fertility levels

Data revealed (Table 4.1 and Fig. 4.2) that increasing levels of fertilizer was significantly differed with respect to number of total tillers m^{-1} row length over control. The significantly highest total number of tillers was found wherein crop was supplied with 100% RDF (95.25) over control and 75% RDF and statistically at par with 125% RDF (96.1).The data further revealed that the per cent increase in number of total tillers m^{-1} row length was in order of 12.80, 23.17 and 24.27 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is clear from the data presented in Table 4.1 and Fig. 4.2 that number of total tillers m^{-1} row length of wheat was significantly affected due to inoculation of liquid biofertilizers as compared to control. The significantly highest no. of tillers (93.51) was recorded under combined application of *Azotobacter* + PSB (B_3) and lowest number of tillers (79.79) was found with no inoculation (B_0). However the treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The number of total tillers m^{-1} row length was increased by 6.85, 6.19 and 17.19 per cent due to inoculation of *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.1.3 Effective Tillers m^{-1} Row Length

Effect of fertility levels

An assessment of data presented in Table 4.1 and Fig. 4.2 revealed that wheat crop responded significantly to each higher level of fertility up to 100% RDF (76.47) but it remained at par with 125% RDF (77.23) in terms of effective tillers m^{-1} row length. The data further revealed that the per cent increase in number of effective tillers m^{-1} row length was in order of 14.13, 21.47 and 22.68 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is evinced from the data (Table 4.1 and Fig. 4.2) that the inoculation of seed with *Azotobacter* + PSB (B_3) was significantly increased the effective tillers m^{-1} row

length. The maximum number of effective tillers m^{-1} row length (75.10) was found with inoculation of *Azotobacter* + PSB (B_3) and minimum number of effective tillers m^{-1} row length (65.42) was observed with no inoculation (B_0).However the treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The effective tillers m^{-1} row length was increased by 6.23, 3.94 and 14.79 per cent due to inoculation of *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.1.4 Test Weight

Effect of fertility levels

A critical examination of data (Table 4.1) showed progressive increase in fertility levels up to 100% RDF (43.9 g) significantly enhanced the test weight of wheat grain over control but it remained at par with 125% RDF (44.2 g). The data further revealed that the per cent increase in test weight was in order of 11, 17.88 and 18.68 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB significantly influenced the test weight over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) recorded maximum test weight (43.36 g). The minimum test weight (38.33 g) was found with no inoculation (B_0). Anyhow, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The test weight was increased by 4.66, 3.67 and 13.12 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.1.5 Grain Yield

Effect of fertility levels

An assessment of data in Table 4.2 and Fig 4.3 indicate that grain yield of wheat was significantly affected with fertility levels as compared to control. The significantly maximum grain yield was found with 100% RDF (4917.51 kg ha^{-1}) over control and 75 % RDF. Whereas, 100% RDF remained at par with 125% RDF (5073.97 kg ha^{-1}). The data further revealed that the per cent increase in grain yield was in order of 51.25, 61.82 and 66.96 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

The grain yield of wheat was significantly affected due to seed inoculation of different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB as compared to control. The highest grain yield (5060.26 kg ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and lowest grain yield (3072.09 kg ha^{-1}) was found with no inoculation (B_0) while treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The grain yield was increased by 44.66, 41.61 and 64.72 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Interaction effect of fertility levels and liquid biofertilizers

The interactive effect of fertility levels and liquid biofertilizers was found significant for grain yield of wheat (Table 4.3 and Fig 4.4). The data revealed that the maximum grain yield (6017.32 kg ha^{-1}) was recorded with combine application of 100% RDF + *Azotobacter* + PSB (F_2B_3) over other treatments but it remained statistically at par with 125% RDF + *Azotobacter* + PSB (F_3B_3). The lowest grain yield (1547.43 kg ha^{-1}) was observed from control (F_0B_0).

4.1.6 Straw Yield

Effect of fertility levels

A critical observation of data presented in Table 4.2 and Fig 4.3 divulged the fact that straw yield was significantly increased with increase in fertility levels as compared to control. The straw yield significantly increased to each higher level of fertility up to 100% RDF (6649.19 kg ha^{-1}) but it remained at par with 125% RDF (6828.19 kg ha^{-1}). The data further revealed that the per cent increase in straw yield was in order of 25.01, 31.83 and 35.38 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An examination from data (Table 4.2 and Fig 4.3) that straw yield of wheat was significantly influenced by seed inoculation with liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB over the control. The highest straw yield (6801.00 kg ha^{-1}) was recorded with inoculation of *Azotobacter* + PSB (B_3) and lowest straw yield (5019.32 kg ha^{-1}) was obtained with no inoculation (B_0). However,

treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The straw yield was increased by 22.25, 20.26 and 35.49 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Interaction effect of fertility levels and liquid biofertilizers

The interactive effect of fertility levels and liquid biofertilizers was found significant for straw yield of wheat (Table 4.4 and Fig 4.5). The data revealed that the maximum straw yield (7274.35 kg ha^{-1}) was recorded with combine application of 100% RDF + *Azotobacter* + PSB (F_2B_3) over other treatments but it remained statistically at par with 125% RDF + *Azotobacter* + PSB (F_3B_3). The lowest straw yield (3560.93 kg ha^{-1}) was observed from control (F_0B_0).

4.1.7 Biological Yield

Effect of fertility levels

Increasing levels in fertility was significantly influenced the biological yield (Table 4.2) over control. The significantly maximum biological yield was found with 100% RDF (11566.7 kg ha^{-1}) but it remained at par with 125% RDF (11902.16 kg ha^{-1}). The data further revealed that the per cent increase in biological yield was in order of 34.88, 43.10 and 47.25 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Evaluation of data (Table 4.2) reflect that biological yield of wheat was significantly influenced by seed inoculation with liquid biofertilizers *viz.*, *Azotobacter*, PSB and *Azotobacter* + PSB over the control. The highest biological yield (11861.26 kg ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and lowest biological yield (8091.41 kg ha^{-1}) was obtained with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The biological yield was increased by 30.76, 28.37 and 46.59 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.1.8 Harvest Index

Effect of fertility levels

An examination of data (Table 4.2) that application effect of fertility levels failed to record any significant effect on harvest index of wheat crop.

Effect of liquid biofertilizers

It is evinced from data (Table 4.2) reflects non significance of seed inoculation with liquid biofertilizers in influencing harvest index of wheat crop.

4.2 NUTRIENT CONTENT AND UPTAKE BY WHEAT CROP

The data pertaining to N, P, K, S, Zn, Fe, Mn and Cu content and their uptake by grain and straw of wheat as influenced by application of fertility levels and seed inoculation with liquid biofertilizers have been summarized in Table 4.5 to 4.14 and analysis of variance in Appendices- VI-VII.

4.2.1 Nutrient Content

4.2.1.1 Nitrogen content in grain

Effect of fertility levels

It is apparent from the data Table 4.5 indicates that nitrogen content in grain of wheat was significantly influenced with the application of fertility levels over control. The nitrogen content in grain was significantly increased to each higher level of fertility up to 100% RDF (1.516%) but it remained at par with 125% RDF (1.519%). The data further revealed that the per cent increase in nitrogen content in grain was in order of 5.22, 7.06 and 7.27 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

A perusal of data (Table 4.5) reflect that seed inoculation with liquid biofertilizers was significantly influenced the nitrogen content in grain of wheat over the control. The highest nitrogen content in grain of wheat (1.518%) was recorded with inoculation of *Azotobacter* + PSB (B_3) and lowest nitrogen content in grain of wheat (1.414%) was found with no inoculation (B_0). Whereas, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The nitrogen content in

grain of wheat was increased by 4.73, 3.96 and 7.35 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.1.2 Nitrogen content in straw

Effect of fertility levels

The experimental finding presented in Table 4.5 indicates that nitrogen content in straw of wheat was significantly influenced with increasing levels of fertilizer over control. The significantly maximum nitrogen content in straw was found with 100% RDF (0.531%) over control and 75% RDF while, remained at par with 125% RDF (0.533%). The data further revealed that the per cent increase in nitrogen content in straw was in order of 11.30, 15.43 and 15.86 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the nitrogen content in straw of wheat over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum nitrogen content in straw of wheat (0.532%). The minimum nitrogen content in straw of wheat (0.457%) was found with no inoculation (B_0). Anyhow, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The nitrogen content in straw was increased by 10.06, 6.67 and 16.41 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.1.3 Phosphorus content in grain

Effect of fertility levels

It is evident from data (Table 4.5) that phosphorus content in grain of wheat was significantly increased with the application of fertility levels over control. The phosphorus content in grain was significantly increased to each higher level of fertility up to 100% RDF (0.322%) but it remained at par with 125% RDF (0.326%). The data further revealed that the per cent increase in phosphorus content in grain was in order of 12.27, 16.24 and 17.68 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Data (Table 4.5) pertaining to phosphorus content in grain shows that phosphorus content in grain of wheat was significantly increased due to seed inoculation with liquid biofertilizers over the control. The highest phosphorus content in grain of wheat (0.325%) was recorded with inoculation of *Azotobacter* + PSB (B_3) and lowest phosphorus content in grain of wheat (0.276%) was found with no inoculation (B_0). Whereas, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The phosphorus content in grain of wheat was increased by 9.05, 7.60 and 17.75per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.1.4 Phosphorus content in straw

Effect of fertility levels

An examination of data (Table 4.5) indicates that phosphorus content in straw of wheat was significantly influenced with increasing levels of fertilizer over control. The significantly maximum phosphorus content in straw was found with 100% RDF (0.209%) over control and 75% RDF and remained at par with 125% RDF (0.211%). The data further revealed that the per cent increase in phosphorus content in straw was in order of 8.55, 11.76 and 12.83 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the phosphorus content in straw of wheat over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum phosphorus content in straw of wheat (0.208%). Minimum phosphorus content in straw of wheat (0.186%) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The phosphorus content in straw of wheat was increased by 6.45, 4.83 and 11.65 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.1.5 Potassium content in grain

Effect of fertility levels

It is apparent from the data Table 4.5 indicates that potassium content in grain of wheat was significantly influenced due to application of fertility levels over control. The potassium content in grain was significantly increased to each higher level of fertility up to 100% RDF (0.535%) but it remained at par with 125% RDF (0.545%). The data further revealed that the per cent increase in potassium content in grain was in order of 7.86, 10.75 and 12.72 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is indicate from the data (Table 4.5) that seed inoculation with liquid biofertilizers was significantly influenced the potassium content in grain of wheat over the control. The maximum potassium content in grain of wheat (0.538%) was recorded with inoculation of *Azotobacter* + PSB (B_3) and minimum potassium content in grain of wheat (0.484%) was observed with no inoculation (B_0). Whereas, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The potassium content in grain of wheat was increased by 5.57, 3.09 and 11.27 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.1.6 Potassium content in straw

Effect of fertility levels

The experimental findings presented in table 4.5 indicates that potassium content in straw of wheat was significantly influenced with increasing levels of fertilizer over control. The significantly maximum potassium content in straw was found with 100% RDF (1.465%) over control and 75% RDF and it remained at par with 125% RDF (1.468%). The data further revealed that the per cent increase in potassium content in straw was in order of 6.69, 8.37 and 9.14 due to application of 7% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

The potassium content in straw was significantly affected due to seed inoculation of different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* +

PSB as compared to control. The maximum potassium content in straw of wheat (1.466%) was observed with inoculation of *Azotobacter* + PSB (B_3). The minimum potassium content in straw of wheat (1.330%) was observed with no inoculation (B_0) and treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The potassium content in straw was increased by 6.09, 4.28 and 10.22 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.1.7 Sulphur content in grain

Effect of fertility levels

It is clear from data (Table 4.5) that sulphur content in grain of wheat was significantly influenced with the application of fertility levels over control. The sulphur content in grain significantly increased to each higher level of fertility up to 100% RDF (0.199%) but it remained at par with 125% RDF (0.202%). The data further revealed that the per cent increase in sulphur content in grain was in order of 11.56, 15.02 and 16.76 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An examination of data (Table 4.5) show that seed inoculation with liquid biofertilizers was significantly influenced the sulphur content in grain of wheat over the control. The highest sulphur content in grain of wheat (0.203%) was recorded with inoculation of *Azotobacter* + PSB (B_3) and lowest sulphur content in grain of wheat (0.170%) was observed with no inoculation (B_0). Whereas, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The sulphur content in grain of wheat was increased by 10.00, 7.64 and 19.41per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.1.8 Sulphur content in straw

Effect of fertility levels

A perusal of data (Table 4.5) reveals that sulphur content in straw of wheat was significantly influenced with increasing levels of fertilizer over control. The

significantly maximum sulphur content in straw was found with 100% RDF (0.157%) over control and 75% RDF and it remained at par with 125% RDF (0.158%). The data further revealed that the per cent increase in sulphur content in straw was in order of 3.45, 8.33 and 9.13 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the sulphur content in straw of wheat over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum sulphur content in straw of wheat (0.161%). The minimum sulphur content in straw of wheat (0.144%) was observed with no inoculation (B_0) and treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The sulphur content in straw of wheat was increased by 5.55, 4.16 and 11.80 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.1.9 Zinc content in grain

Effect of fertility levels

It is evinced from data (Table 4.6) that increasing levels of fertilizer was significantly differed with respect to zinc content in grain over control. The significantly highest zinc content in grain was found wherein crop was supplied with 100% RDF (26.92 mg kg^{-1}) over control and 75% RDF and it remained statistically at par with 125% RDF (26.95 mg kg^{-1}). The data further revealed that the per cent increase in zinc content in grain was in order of 1.73, 3.53 and 3.65 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

A perusal of data (Table 4.6) reflects non significance effect of seed inoculation with liquid biofertilizers on zinc content in grain of wheat crop.

4.2.1.10 Zinc content in straw

Effect of fertility levels

The experimental findings presented in Table 4.6 indicates that zinc content in straw of wheat was significantly influenced with increasing levels of fertilizer over control. The significantly highest zinc content in straw was found with 100% RDF (13.64 mg kg^{-1}) over control and 75% RDF and it remained at par with 125% RDF (13.65 mg kg^{-1}). The data further revealed that the per cent increase in zinc content in straw was in order of 1.51, 3.09 and 3.17 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

A perusal of data (Table 4.6) reflects non significance effect of seed inoculation with liquid biofertilizers on zinc content in straw of wheat crop.

4.2.1.11 Iron content in grain

Effect of fertility levels

It is apparent from data (Table 4.6) that increasing levels of fertilizer was significantly differed with respect to iron content in grain over control. The significantly highest iron content in grain was found wherein crop was supplied with 100% RDF (75.91mg kg^{-1}) over control and 75% RDF and it remained statistically at par with 125% RDF (76.09 mg kg^{-1}).The data further revealed that the per cent increase in iron content in grain was in order of 2.69, 4.12 and 4.37 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Data explicate (Table 4.6) that non significance effect of seed inoculation with liquid biofertilizers on iron content in grain of wheat crop.

4.2.1.12 Iron content in straw

Effect of fertility levels

An assessment of data presented in Table 4.6 revealed that wheat crop responded significantly to each higher level of fertility up to 100% RDF (148.66mg kg^{-1}) but it remained at par with 125% RDF (148.89 mg kg^{-1}) in terms of iron content

in straw. The data further revealed that the per cent increase in iron content in straw was in order of 1.55, 2.78 and 2.94due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Data explicate (Table 4.6) that non significance effect of seed inoculation with liquid biofertilizers on iron content in straw of wheat crop.

4.2.1.13 Manganese content in grain

Effect of fertility levels

An examination of data (Table 4.6) show that manganese content in grain of wheat was significantly influenced due to application of fertility levels over control. The manganese content in grain was significantly increased to each higher level of fertility up to 100% RDF (13.95mg kg^{-1}) but it remained at par with 125% RDF (13.97mg kg^{-1}).The data further revealed that the per cent increase in manganese content in grain was in order of 2.51, 5.25 and 5.40due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is evinced from data (Table 4.6) that non significance effect of seed inoculation with liquid biofertilizers on manganese content in grain of wheat crop.

4.2.1.14 Manganese content in straw

Effect of fertility levels

The experimental findings presented in Table 4.6 indicates that manganese content in straw of wheat was significantly influenced with increasing levels of fertilizer over control. The significantly highest manganese content in straw was found with 100% RDF (22.32 mg kg^{-1}) over control and 75% RDF while, it remained at par with 125% RDF (22.51mg kg^{-1}).The data further revealed that the per cent increase in manganese content in straw was in order of 2.26, 4.96 and 5.88 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is evinced from data (Table 4.6) that non significance effect of seed inoculation with liquid biofertilizers on manganese content in straw of wheat crop.

4.3.1.15 Copper content in grain

Effect of fertility levels

It is apparent from data (Table 4.6) that increasing levels of fertilizer was significantly differed with respect to copper content in grain over control. The significantly highest copper content in grain was found wherein crop was supplied with 100% RDF (7.86mg kg^{-1}) over control and 75% RDF while, it remained at par with 125% RDF (7.87mg kg^{-1}).The data further revealed that the per cent increase in copper content in grain was in order of 1.90, 3.74 and 3.88 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Data present in table 4.6 reflects non significance effect of seed inoculation with liquid biofertilizers on copper content in grain of wheat crop.

4.3.1.16 Copper content in straw

Effect of fertility levels

An assessment of data presented in Table 4.6 revealed that wheat crop responded significantly to each higher level of fertility up to 100% RDF (3.64 mg kg^{-1}) but it remained at par with 125% RDF (3.66mg kg^{-1}) in terms of copper content in straw. The data further revealed that the per cent increase in copper content in straw was in order of 4.96, 9.21 and 9.75 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Data present in table 4.6 reflects non significance effect of seed inoculation with liquid biofertilizers on copper content in straw of wheat crop.

4.2.2 Nutrient Uptake by Grain and Straw

4.2.2.1 Nitrogen uptake by grain

Effect of fertility levels

It is explicated from the data (Table 4.7 and Fig 4.6) that application of fertility levels was significantly influenced the nitrogen uptake by grain of wheat over the control. The nitrogen uptake by grain of wheat significantly increased to each higher level of fertility up to 100% RDF (74.54 kg ha^{-1}) but it remained at par with 125% RDF (77.07 kg ha^{-1}). The data further revealed that the per cent increase in nitrogen uptake by grain of wheat was in order of 43.12, 74.37 and 79.06 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

A critical examination of the data Table 4.7 and Fig 4.6 indicates that nitrogen uptake by grain of wheat was significantly influenced due to seed inoculation with liquid biofertilizers over the control. The highest nitrogen uptake by grain of wheat (76.81 kg ha^{-1}) was recorded with inoculation of *Azotobacter* + PSB (B_3) and lowest nitrogen uptake by grain of wheat (43.43 kg ha^{-1}) was found with no inoculation (B_0). Whereas, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The nitrogen uptake by grain of wheat was increased by 44.18, 37.09and 63.93 per cent due to application *Azotobacter* (B_1),PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Interaction effect of fertility levels and liquid biofertilizers

The interactive effect of fertility levels and liquid biofertilizers was found significant for nitrogen uptake by grain of wheat (Table 4.8 and Fig. 4.7). The data revealed that the maximum nitrogen uptake by grain of wheat (96.36kg ha^{-1}) was recorded with combine application of 100% RDF + *Azotobacter* + PSB (F_2B_3) over other treatments but it remained statistically at par with 125% RDF + *Azotobacter* + PSB (F_3B_3). The lowest nitrogen uptake by grain of wheat (21.27 kg ha^{-1}) was observed from control (F_0B_0).

4.2.2.2 Nitrogen uptake by straw

Effect of fertility levels

It is indicate from the data (Table 4.7 and Fig 4.6) that increasing levels of fertilizer was significantly differed with respect to nitrogen uptake by straw of wheat over control. The significantly highest nitrogen uptake by straw of wheat was found wherein crop was supplied with 100% RDF (35.30 kg ha^{-1}) over control and 75% RDF while, it remained statistically at par with 125% RDF (36.39 kg ha^{-1}).The data further revealed that the per cent increase in nitrogen uptake by straw of wheat was in order of 39.13, 52.15 and 56.85 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the nitrogen uptake by straw of wheat over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum nitrogen uptake by straw of wheat (36.18kg ha^{-1}). The minimum nitrogen uptake by straw of wheat (22.93 kg ha^{-1}) was found with no inoculation (B_0).

However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The nitrogen uptake by straw of wheat was increased by 34.58, 28.43 and 57.78 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Interaction effect of fertility levels and liquid biofertilizers

The interactive effect of fertility levels and liquid biofertilizers was found significant for nitrogen uptake by straw of wheat (Table 4.9 and Fig 4.8). The data revealed that the maximum nitrogen uptake by straw of wheat (42.33kg ha^{-1}) was recorded with combine application of 100% RDF + *Azotobacter* + PSB (F_2B_3) over other treatments but it remained statistically at par with 125% RDF + *Azotobacter* + PSB (F_3B_3). The lowest nitrogen uptake by straw of wheat (14.80 kg ha^{-1}) was observed from control (F_0B_0).

4.2.2.3 Phosphorus uptake by grain

Effect of fertility levels

An assessment of data in Table 4.7 and Fig 4.9 reflects that wheat crop responded significantly to each higher level of fertility up to 100% RDF (15.83 kg ha^{-1}) but it remained at par with 125% RDF (16.54 kg ha^{-1}) in terms of phosphorus uptake by grain of wheat. The data further revealed that the per cent increase in phosphorus uptake by grain of wheat was in order of 45.35, 90.22 and 94.50 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

The phosphorus uptake by grain was significantly affected due to seed inoculation of different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB as compared to control. The maximum phosphorus uptake by grain of wheat (16.44 kg ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3). The minimum phosphorus uptake by grain of wheat (8.47 kg ha^{-1}) was observed with no inoculation (B_0).However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The phosphorus uptake by grain of wheat was increased by 53.64, 46.31 and 78.56 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Interaction effect of fertility levels and liquid biofertilizers

The interactive effect of fertility levels and liquid biofertilizers was found significant for phosphorus uptake by grain of wheat (Table 4.10 and Fig 4.10). The data revealed that the maximum phosphorus uptake by grain of wheat (20.98 kg ha^{-1}) was recorded with combine application of 100% RDF + *Azotobacter* + PSB (F_2B_3) over other treatments but it remained statistically at par with 125% RDF + *Azotobacter* + PSB (F_3B_3). The minimum phosphorus uptake by grain of wheat (3.87 kg ha^{-1}) was observed from control (F_0B_0).

4.2.2.4 Phosphorus uptake by straw

Effect of fertility levels

The experimental findings presented in Table 4.7 indicates that phosphorus uptake by straw of wheat was significantly influenced with increasing levels of fertilizer over control. The significantly maximum phosphorus uptake by straw of

wheat was found with 100% RDF (13.89 kg ha^{-1}) over control and 75% RDF while, it remained at par with 125% RDF (14.40 kg ha^{-1}). The data further revealed that the per cent increase in phosphorus uptake by straw of wheat was in order of 35.63, 47.29 and 52.70 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An assessment of data (Table 4.7 and Fig 4.9) reflects that phosphorus uptake by straw of wheat was significantly influenced due to seed inoculation with liquid biofertilizers over the control. The maximum phosphorus uptake by straw of wheat (14.14kg ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and minimum phosphorus uptake by straw of wheat (9.33 kg ha^{-1}) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The phosphorus uptake by straw of wheat was increased by 30.22, 26.15 and 51.55 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Interaction effect of fertility levels and liquid biofertilizers

The interactive effect of fertility levels and liquid biofertilizers was found significant for phosphorus uptake by straw of wheat (Table 4.11 and Fig 4.11). The data revealed that the maximum phosphorus uptake by straw of wheat (15.94 kg ha^{-1}) was recorded with combine application of 100% RDF + *Azotobacter* + PSB (F_2B_3) over other treatments but it remained statistically at par with 125% RDF + *Azotobacter* + PSB (F_3B_3). The lowest phosphorus uptake by straw of wheat (6.10 kg ha^{-1}) was observed from control (F_0B_0).

4.2.2.5 Potassium uptake by grain

Effect of fertility levels

It is indicate from the data (Table 4.7 and Fig 4.12) that application of fertility levels was significantly influenced the potassium uptake by grain of wheat over the control. The potassium uptake by grain of wheat was significantly increased to each higher level of fertility up to 100% RDF (26.30 kg ha^{-1}) but it remained at par with 125% RDF (27.65 kg ha^{-1}). The data further revealed that the per cent increase in

potassium uptake by grain of wheat was in order of 42.00, 82.19 and 88.97 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the potassium uptake by grain of wheat over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum potassium uptake by grain of wheat (27.22kg ha^{-1}). The minimum potassium uptake by grain of wheat (14.86 kg ha^{-1}) was found with no inoculation (B_0). Anyhow, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The potassium uptake by grain of wheat was increased by 48.08, 41.27 and 70.77 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Interaction effect of fertility levels and liquid biofertilizers

The interactive effect of fertility levels and liquid biofertilizers was found significant for potassium uptake by grain of wheat (Table 4.12 and Fig. 4.13). The data revealed that the maximum potassium uptake by grain of wheat (35.47kg ha^{-1}) was recorded with combine application of 100% RDF + *Azotobacter* + PSB (F_2B_3) over other treatments but it remained statistically at par with 125% RDF + *Azotobacter* + PSB (F_3B_3). The lowest potassium uptake by grain of wheat (7.24 kg ha^{-1}) was observed from control (F_0B_0).

4.2.2.6 Potassium uptake by stover

Effect of fertility levels

A critical examination of data (Table 4.7 and Fig 4.12) indicates that wheat crop responded significantly to each higher level of fertility up to 100% RDF (97.41 kg ha^{-1}) but it remained at par with 125% RDF (100.23 kg ha^{-1}) in terms of potassium uptake by straw of wheat. The data further revealed that the per cent increase in potassium uptake by straw of wheat was in order of 33.39, 43.60 and 47.76 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

The potassium uptake by straw of wheat was significantly affected due to seed inoculation of different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB as compared to control. The maximum potassium uptake by straw of wheat (99.70kg ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3). The minimum potassium uptake by straw of wheat (66.75 kg ha^{-1}) was observed with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The potassium uptake by straw of wheat was increased by 29.70, 25.42 and 49.36 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Interaction effect of fertility levels and liquid biofertilizers

The interactive effect of fertility levels and liquid biofertilizers was found significant for potassium uptake by straw of wheat (Table 4.13 and Fig 4.14). The data revealed that the maximum potassium uptake by straw of wheat (112.38 kg ha^{-1}) was recorded with combine application of 100% RDF + *Azotobacter* + PSB (F_2B_3) over other treatments but it remained statistically at par with 125% RDF + *Azotobacter* + PSB (F_3B_3). The lowest potassium uptake by straw of wheat (45.32 kg ha^{-1}) was observed from control (F_0B_0).

4.2.2.7 Sulphur uptake by grain

Effect of fertility levels

It is evinced from the data (Table 4.7) that application of fertility levels was significantly influenced the sulphur uptake by grain of wheat over the control. The sulphur uptake by grain of wheat was significantly increased to each higher level of fertility up to 100% RDF (9.78 kg ha^{-1}) but it remained at par with 125% RDF (10.24 kg ha^{-1}). The data further revealed that the per cent increase in sulphur uptake by grain of wheat was in order of 44.86, 89.35 and 94.03 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An assessment of data (Table 4.7) reflects that sulphur uptake by grain of wheat was significantly influenced due to seed inoculation with liquid biofertilizers over the control. The maximum sulphur uptake by grain of wheat (10.27kg ha^{-1}) was

recorded with inoculation of *Azotobacter* + PSB (B_3) and minimum sulphur uptake by grain of wheat (5.22 kg ha^{-1}) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The sulphur uptake by grain of wheat was increased by 53.99, 45.86 and 80.00 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.2.8 Sulphur uptake by straw

Effect of fertility levels

Data (Table 4.7) pertaining to sulphur uptake by straw was significantly influenced with increasing levels of fertilizer over control. The significantly maximum sulphur uptake by straw of wheat was found with 100% RDF (10.43 kg ha^{-1}) over control and 75 % RDF while, it remained at par with 125% RDF (10.78 kg ha^{-1}). The data further revealed that the per cent increase in sulphur uptake by straw of wheat was in order of 31.87, 42.68 and 47.46 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the sulphur uptake by straw of wheat over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum sulphur uptake by straw of wheat (10.94kg ha^{-1}). The minimum sulphur uptake by straw of wheat (7.22 kg ha^{-1}) was found with no inoculation (B_0) and treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The sulphur uptake by straw of wheat was increased by 29.08, 25.38 and 51.52 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.2.9 Zinc uptake by grain

Effect of fertility levels

The experimental findings present in Table 4.14 indicates that increasing levels of fertilizer was significantly differed with respect to zinc uptake by grain in wheat. The significantly highest zinc uptake by grain in wheat was found wherein crop was supplied with 100% RDF (132.37 g ha^{-1}) over control and 75% RDF while,

it remained statistically at par with 125% RDF (136.74 g ha^{-1}).The data further revealed that the per cent increase in zinc uptake by grain was in order of 53.87, 67.53 and 73.06 due to application of 75 % RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is indicate from the data (Table 4.14) that zinc uptake by grain of wheat was significantly influenced due to seed inoculation with liquid biofertilizers over the control. The maximum zinc uptake by grain of wheat (133.94 g ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and minimum zinc uptake by grain of wheat (80.30 g ha^{-1}) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The zinc uptake by grain of wheat was increased by 46.05, 42.80 and 66.79 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.2.10 Zinc uptake by straw

Effect of fertility levels

An assessment of data presented in Table 4.14 revealed that wheat crop responded significantly to each higher level of fertility up to 100% RDF (90.69 g ha^{-1}) but it remained at par with 125% RDF (93.20 g ha^{-1}) in terms of zinc uptake by straw of wheat. The data further revealed that the per cent increase in zinc uptake by straw of wheat was in order of 26.90, 35.92 and 39.68 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

The zinc uptake by straw of wheat was significantly affected due to seed inoculation of different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB as compared to control. The maximum zinc uptake by stover of wheat (91.33g ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3). The minimum zinc uptake by straw of wheat (66.50g ha^{-1}) was observed with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The zinc uptake by straw was increased by 22.72, 20.63 and 37.33per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.2.11 Iron uptake by grain

Effect of fertility levels

It is apparent from the data (Table 4.14) that iron uptake by grain in wheat was significantly influenced with increasing levels of fertilizer over control. The significantly maximum iron uptake by grain in wheat was found with 100% RDF (373.31 g ha^{-1}) over control and 75% RDF while, it remained at par with 125% RDF (386.09 g ha^{-1}). The data further revealed that the per cent increase in iron uptake by grain in wheat was in order of 55.32, 68.49 and 74.26 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the iron uptake by grain of wheat over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum iron uptake by grain of wheat (382.42 g ha^{-1}). The minimum iron uptake by grain of wheat (224.11 g ha^{-1}) was found with no inoculation (B_0). Anyhow, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The iron uptake by grain was increased by 49.24, 43.63 and 70.63 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.2.12 Iron uptake by straw

Effect of fertility levels

An assessment of data in Table 4.14 indicates that iron uptake by straw in wheat was significantly influenced with application of fertility levels over the control. The iron uptake by straw of wheat was significantly increased to each higher level of fertility up to 100% RDF (988.46 g ha^{-1}) but it remained at par with 125% RDF (1016.69 g ha^{-1}). The data further revealed that the per cent increase in iron uptake by straw was in order of 26.96, 35.50 and 39.37due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is indicate from the data (Table 4.14) that seed inoculation with liquid biofertilizers was significantly increased the iron uptake by straw of wheat over the control. The maximum iron uptake by straw (1012.28g ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and minimum iron uptake by straw (727.06 g ha^{-1}) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The iron uptake by straw was increased by 24.87, 21.95 and 39.22per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.2.13 Manganese uptake by grain

Effect of fertility levels

Data (Table 4.14) divulge the fact that manganese uptake by grain in wheat was significantly influenced with increasing levels of fertilizer over control. The significantly maximum manganese uptake by grain in wheat was found with 100% RDF (68.61 g ha^{-1}) over control and 75% RDF while, it remained at par with 125% RDF (70.89 g ha^{-1}). The data further revealed that the per cent increase in manganese uptake by grain was in order of 55.06, 70.33 and 75.99 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

The manganese uptake by grain of wheat was significantly affected due to seed inoculation of different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB as compared to control. The maximum manganese uptake by grain of wheat (70.28 g ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3). The minimum manganese uptake by grain of wheat (41.49g ha^{-1}) was observed with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The manganese uptake by grain was increased by 46.22, 41.79 and 69.39 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.2.14 Manganese uptake by straw

Effect of fertility levels

Evaluation of data (Table 4.14) reflects that increasing levels of fertilizer was significantly differed with respect to manganese uptake by straw in wheat over control. The significantly highest manganese uptake by straw in wheat was found wherein crop was supplied with 100% RDF (148.40g ha^{-1}) over control and 75% RDF while, it remained statistically at par with 125% RDF (153.75 g ha^{-1}). The data further revealed that the per cent increase in manganese uptake by straw was in order of 27.84, 38.36 and 43.35 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is clear from data in Table 4.14 indicates that seed inoculation with liquid biofertilizers was significantly influenced the manganese uptake by straw of wheat over the control. The highest manganese uptake by straw (147.60g ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and lowest manganese uptake by straw (107.65g ha^{-1}) was observed with no inoculation (B_0). Whereas, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The manganese uptake by straw was increased by 23.66, 20.28 and 37.11 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.2.15 Copper uptake by grain

Effect of fertility levels

It apparent from data (Table 4.14) that wheat crop responded significantly to each higher level of fertility up to 100% RDF (38.65g ha^{-1}) but it remained at par with 125% RDF (39.93 g ha^{-1}) in terms of copper uptake by grain of wheat. The data further revealed that the per cent increase in copper uptake by grain was in order of 54.12, 67.89 and 73.45 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the copper uptake by grain of wheat over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum copper uptake by grain of wheat (39.41g ha^{-1}). The minimum copper uptake by grain of wheat (23.63g ha^{-1}) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The copper uptake by grain was increased by 42.99, 39.94 and 66.77 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.2.2.16 Copper uptake by straw

Effect of fertility levels

It is obvious from data (Table 4.14) indicates that copper uptake by straw in wheat was significantly influenced with the application of fertility levels over the control. The copper uptake by straw of wheat was significantly increased to each higher level of fertility up to 100% RDF (24.26g ha^{-1}) but it remained at par with 125% RDF (25.03g ha^{-1}). The data further revealed that the per cent increase in copper uptake by straw was in order of 31.21, 43.97 and 48.50 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

A perusal of data in Table 4.14 indicates that seed inoculation with liquid biofertilizers was significantly influenced the copper uptake by straw of wheat over the control. The highest copper uptake by straw (23.81 g ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and lowest copper uptake by straw (16.98 g ha^{-1}) was observed with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The copper uptake by straw was increased by 26.61, 27.32 and 40.22 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.3 SOIL PROPERTIES AFTER HARVEST OF WHEAT CROP

4.3.1 Bulk Density

Effect of fertility levels

It is perusal from data (Table 4.15) that application of fertility levels failed to record any significant effect on bulk density of soil after harvest of wheat crop.

Effect of liquid biofertilizers

It is evident from data (Table 4.15) reflects non significance of seed inoculation with liquid biofertilizers on bulk density of soil after harvest of wheat crop.

4.3.2 Particle Density

Effect of fertility levels

It is obvious from data (Table 4.15) that application of fertility levels failed to record any significant effect on particle density of soil after harvest of wheat crop.

Effect of liquid biofertilizers

An evaluation of data (Table 4.15) reflects non significance of seed inoculation with liquid biofertilizers on particle density of soil after harvest of wheat crop.

4.3.3 Porosity

Effect of fertility levels

An examination of data (Table 4.15) that application of fertility levels failed to record any significant effect on porosity of soil after harvest of wheat crop.

Effect of liquid biofertilizers

Data divulge in Table 4.15 reflects non significance of seed inoculation with liquid biofertilizers on porosity of soil after harvest of wheat crop.

4.3.4 pH

Effect of fertility levels

It is apparent from data (Table 4.15) that application of fertility levels failed to record any significant effect on pH of soil after harvest of wheat crop.

Effect of liquid biofertilizers

Data present in Table 4.15reflects non significance of seed inoculation with liquid biofertilizers on pH of soil after harvest of wheat crop.

4.3.5 Electrical Conductivity

Effect of fertility levels

It is evinced from data (Table 4.15) that application of fertility levels failed to record any significant effect on electrical conductivity of soil after harvest of wheat crop.

Effect of liquid biofertilizers

An examination of data (Table 4.15) show that seed inoculation with liquid biofertilizers not influence the electrical conductivity of soil after harvest of wheat crop.

4.3.6 Organic Carbon

Effect of fertility levels

It is clear from data (Table 4.15) that application of fertility levels failed to record any significant effect on organic carbon of soil after harvest of wheat crop.

Effect of liquid biofertilizers

Data pertaining in Table 4.15 show that non significance of seed inoculation with liquid biofertilizers on organic carbon of soil after harvest of wheat crop.

4.3.7 Available Nitrogen

Effect of fertility levels

It is apparent from data (Table 4.16) that available nitrogen in soil was significantly increased with the application of fertility levels over the control. The available nitrogen significantly increased to each higher level of fertility up to 100% RDF (305.10 kg ha^{-1}) but it remained at par with 125% RDF (308.31 kg ha^{-1}). The data further revealed that the per cent increase in available nitrogen in soil was in order of 8.99, 12.88 and 14.07 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An assessment of data in Table 4.16 reflects that available nitrogen of soil was significantly increased due to seed inoculation with liquid biofertilizers over the control. The maximum available nitrogen (303.73 kg ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and minimum available nitrogen (276.36 kg ha^{-1}) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The available nitrogen in soil was increased by 6.09, 4.04 and 9.90 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.3.8 Available Phosphorus

Effect of fertility levels

Data (Table 4.16) divulge the fact that increasing levels of fertilizer was significantly differed with respect to available phosphorus in soil over control. The significantly highest available phosphorus was found wherein crop was supplied with 100% RDF (25.28 kg ha^{-1}) over control and 75% RDF while, it statistically at par with 125% RDF (25.53 kg ha^{-1}).The available phosphorus in soil was increased by 15.75, 20.32 and 21.51 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Effect of liquid biofertilizers

The available phosphorus of soil was significantly affected due to seed inoculation of different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB as compared to control. The maximum available phosphorus of soil (25.20 kg ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3). The minimum available phosphorus of soil (21.09 kg ha^{-1}) was observed with no inoculation (B_0). Anyhow, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The available phosphorus in soil was increased by 7.72, 11.14 and 19.48 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.3.9 Available Potassium

Effect of fertility levels

Data (Table 4.16) divulge the fact that available potassium was significantly influenced with increasing levels of fertilizer over control. The significantly maximum available potassium was found with 100% RDF (445.80 kg ha^{-1}) over control and 75% RDF while, it remained at par with 125% RDF (447.57 kg ha^{-1}). The data further revealed that the per cent increase in available potassium in soil was in order of 11.51, 15.24 and 15.70 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB significantly influenced the available potassium in soil over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum available potassium in soil (447.08 kg ha^{-1}). The minimum available potassium in soil (378.14 kg ha^{-1}) was found with no inoculation (B_0) and treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The available potassium in soil was increased by 9.61, 7.03 and 18.23 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.3.10 Available Sulphur

Effect of fertility levels

Data (Table 4.16) divulge the fact that available sulphur in soil was significantly increased with application of fertility levels over the control. The available sulphur significantly increased to each higher level of fertility up to 100% RDF (10.16 mg ha^{-1}) but it remained at par with 125% RDF (10.18 mg ha^{-1}). The data further revealed that the per cent increase in available sulphur in soil was in order of 7.93, 11.41 and 11.74 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

It is evinced from data (Table 4.16) that available sulphur in soil was significantly increased due to seed inoculation with liquid biofertilizers over the

control. The highest available sulphur (9.92 mg ha^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and lowest available sulphur (9.49 mg ha^{-1}) was found with no inoculation (B_0). Whereas, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The available sulphur in soil was increased by 2.46, 1.50 and 4.53 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.3.11 Available Zinc

Effect of fertility levels

Data revealed (Table 4.16) that increasing levels of fertilizer was significantly differed with respect to available zinc in soil after harvest of wheat crop. The significantly highest available zinc was found wherein crop was supplied with 100% RDF (0.73 mg kg^{-1}) over control and 75% RDF while, it remained statistically at par with 125% RDF (0.74 mg kg^{-1}).The data further revealed that the per cent increase in available zinc in soil was in order of 4.45, 9.21 and 9.80 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An examination of data (Table 4.16) reflects non significance of seed inoculation with liquid biofertilizers on available zinc in soil after harvest of wheat crop.

Effect of fertility levels

It is evinced from data (Table 4.16) that available iron in soil after harvest of wheat crop was significantly influenced with increasing levels of fertilizer over control. The significantly maximum available iron in soil was found with 100% RDF (5.57 mg kg^{-1}) over control and 75% RDF while, it remained at par with 125% RDF (5.58mg kg^{-1}).The data further revealed that the per cent increase in available iron in soil was in order of 15.90, 28.04 and 28.48 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An examination of data (Table 4.16) reflects non significance of seed inoculation with liquid biofertilizers on available iron in soil after harvest of wheat crop.

4.3.13 Available Manganese

Effect of fertility levels

It is apparent from data (Table 4.16) that available manganese in soil after harvest of wheat crop was significantly influenced due to application of fertility levels over control. The available manganese in soil significantly increased to each higher level of fertility up to 100% RDF (9.76 mg kg^{-1}) but it remained at par with 125% RDF (9.82 mg kg^{-1}). The data further revealed that the per cent increase in available manganese in soil was in order of 4.93, 9.53 and 10.21 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Data pertaining in Table 4.16 shows that non significance of seed inoculation with liquid biofertilizers on available manganese in soil after harvest of wheat crop.

4.3.14 Available Copper

Effect of fertility levels

It is clear from data (Table 4.16) that wheat crop responded significantly to each higher level of fertility up to 100% RDF (2.10mg kg^{-1}) but it remained at par with 125% RDF (2.11mg kg^{-1}) in terms of available copper in soil after harvest of wheat crop. The data further revealed that the per cent increase in available copper in soil was in order of 1.26, 2.52 and 2.67 8due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Data present in Table 4.16 reflects non significance of seed inoculation with liquid biofertilizers on available copper in soil after harvest of wheat crop.

4.4 SOIL BIOLOGICAL PROPERTIES

4.4.1 Microbial Population

4.4.1.1 Bacterial population

Effect of fertility levels

An assessment of data (Table 4.17 and Fig. 4.15) shows that bacterial population in soil was significantly increased with application of fertility levels over

the control. The bacterial population significantly increased to each higher level of fertility up to 100% RDF (73.62× 10^7 cfu g^{-1} of soil) but it remained at par with 125% RDF (75.29× 10^7 cfu g^{-1} of soil). The data further revealed that the per cent increase in bacterial population in soil was in order of 8.67, 15.26 and 18.30 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An examination from data (Table 4.17 and Fig. 4.15) shows that bacterial population in soil was significantly increased due to seed inoculation with liquid biofertilizers over the control. The maximum bacterial population (75.88 × 10^7 cfu g^{-1} of soil) was observed with inoculation of *Azotobacter* + PSB (B_3) and minimum bacterial population (63.41 × 10^7cfu g^{-1} of soil) was found with no inoculation (B_0). Whereas, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The bacterial population in soil was increased by 13.02, 11.46 and 19.66 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

Interaction effect of fertility levels and liquid biofertilizers

The interactive effect of fertility levels and liquid biofertilizers was found significant for bacterial population in soil (Table 4.18 and Fig. 4.16). The data revealed that the maximum bacterial population in soil (81.31 × 10^7cfu g^{-1} of soil) was recorded with combine application of 100% RDF + *Azotobacter* + PSB (F_2B_3)over other treatments but it remained statistically at par with 125% RDF + *Azotobacter* + PSB (F_3B_3). The lowest bacterial population in soil (55.63× 10^7 cfu g^{-1} of soil) was observed from control (F_0B_0).

4.4.1.2 Fungal population

Effect of fertility levels

It is evinced from data (Table 4.17 and Fig. 4.15) that fungal population in soil was significantly influenced with increasing levels of fertilizer over control. The significantly maximum fungal population in soil was found with 100% RDF (25.42 × 10^5 cfu g^{-1} of soil) over control and 75% RDF and remained at par with 125% RDF (25.81× 10^5 cfu g^{-1} of soil). The data further revealed that the per cent increase in fungal population in soil was in order of 4.48, 8.67 and 10.34 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the fungal population in soil over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum fungal population in soil (27.33×10^5 cfu g^{-1} of soil). The minimum fungal population in soil (22.44×10^5cfu g^{-1} of soil) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The fungal population in soil was increased by 11.76, 9.98 and 21.76 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.4.1.3 Actinomycetes population

Effect of fertility levels

It is apparent from data (Table 4.17 and Fig. 4.15) that actinomycetes population in soil was significantly increased with application of fertility levels over the control. The actinomycetes population significantly increased to each higher level of fertility up to 100% RDF (40.66×10^6 cfu g^{-1} of soil) but it remained at par with 125% RDF (40.86×10^6 cfu g^{-1} of soil).The data further revealed that the per cent increase in actinomycetes population in soil was in order of 9.77, 16.57 and 17.44 due to application of 75% RDF (F_1), 100% RDF (F_2) and125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Data (Table 4.17 and Fig. 4.15) divulge the fact that actinomycetes population in soil was significantly increased due to seed inoculation with liquid biofertilizers over the control. The maximum actinomycetes population (41.61×10^6 cfu g^{-1} of soil) was recorded with inoculation of *Azotobacter* + PSB (B_3) and minimum actinomycetes population (34.83×10^6cfu g^{-1} of soil) was observed with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The actinomycetes population in soil was increased by 12.77, 11.76 and 19.46 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.4.2 Soil Microbial Biomass and Enzyme Activities

4.4.2.1 Soil microbial biomass carbon

Effect of fertility levels

Evaluation of data (Table 4.17 and Fig. 4.17) show that soil microbial biomass carbon in soil was significantly influenced due to application of fertility levels over control. The soil microbial biomass carbon in soil significantly increased to each higher level of fertility up to 100% RDF (185.70 mg kg^{-1}) but it remained at par with 125% RDF (188.98mg kg^{-1}). The data further revealed that the per cent increase in soil microbial biomass carbon in soil was in order of 6.45, 11.95 and 13.96 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

The soil microbial biomass carbon in soil was significantly affected due to seed inoculation of different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB as compared to control. The maximum soil microbial biomass carbon in soil (189.48mg kg^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3). The minimum soil microbial biomass carbon in soil (169.92mg kg^{-1}) was observed with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The soil microbial biomass carbon in soil was increased by 5.68, 4.75 and11.51 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.4.2.2 Soil microbial biomass nitrogen

Effect of fertility levels

It is clear from data (Table 4.17 and Fig. 4.17) that soil microbial biomass nitrogen in soil was significantly increased with application of fertility levels over the control. The soil microbial biomass nitrogen significantly increased to each higher level of fertility up to 100% RDF (27.88 mg kg^{-1}) but it remained at par with 125% RDF (28.65mg kg^{-1}). The data further revealed that the per cent increase in soil microbial biomass nitrogen in soil was in order of 4.73, 10.89 and 13.96 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An examination from data (Table 4.17 and Fig. 4.17) that soil microbial biomass nitrogen in soil was significantly increased due to seed inoculation with liquid biofertilizers over the control. The highest soil microbial biomass nitrogen (29.18mg kg^{-1}) was observed with inoculation of *Azotobacter* + PSB (B_3) and lowest soil microbial biomass nitrogen (24.90mg kg^{-1}) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The soil microbial biomass nitrogen in soil was increased by 9.91, 6.53 and 17.18 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.4.2.3 Dehydrogenase activities

Effect of fertility levels

It is obvious from data presented in Table 4.17 and Fig. 4.18 that dehydrogenase activity in soil was significantly influenced with increasing levels of fertilizer over control. The significantly maximum dehydrogenase activity in soil was found with 100% RDF (13.53 µg TPF g^{-1} 24 h^{-1}) over control and 75% RDF while, it remained at par with 125% RDF (13.77 µg TPF g^{-1} 24 h^{-1}). The data further revealed that the per cent increase in dehydrogenase activity in soil was in order of 16.38, 35.99 and 38.38 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the dehydrogenase activity in soil over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum dehydrogenase activity in soil (13.91µg TPF g^{-1} 24 h^{-1}). The minimum dehydrogenase activity in soil (9.92 µg TPF g^{-1} 24 h^{-1}) was found with no inoculation (B_0). Whereas, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The dehydrogenase activity in soil increased by 27.01, 25.100 and 40.22 per cent due to application *Azotobacter* (B_1),PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.4.2.4 Alkaline phosphate activity

Effect of fertility levels

Data present in Table 4.17 and Fig. 4.18 shows that increasing levels of fertilizer was significantly differed with respect to alkaline phosphate activity in soil over control. The significantly highest alkaline phosphate activity in soil was found wherein crop was supplied with 100% RDF (20.21 µg PNP g^{-1} ha^{-1}) over control and 75% RDF while, it remained statistically at par with 125% RDF (20.61 µg PNP g^{-1} ha^{-1}).The data further revealed that the per cent increase in alkaline phosphate activity in soil was in order of 14.43, 32.61 and 29.94 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter,* PSB and *Azotobacter* + PSB was significantly influenced the alkaline phosphate activity in soil over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum alkaline phosphate activity in soil (21.61 µg PNP g^{-1} ha^{-1}). The minimum alkaline phosphate activity in soil (15.70 µg PNP g^{-1} ha^{-1}) was found with no inoculation (B_0) and treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The alkaline phosphate activity in soil was increased by 19.93, 19.03 and 37.64 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.5 ECONOMICS

4.5.1 Net Return

Effect of fertility levels

Data present in Table 4.19 shows that net return was significantly increased with application of fertility levels over the control. The net return was significantly increased to each higher level of fertility up to 100% RDF (99341.18 ` $ha^{-1}$) but it remained at par with 125% RDF (99437.04 ` ha^{-1}). The data further revealed that the per cent increase in net return was in order of 55.13, 68.21 and 67.71 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

An examination from data (Table 4.19) that net return was significantly increased due to seed inoculation with liquid biofertilizers over the control. The highest net return (102675.54 ` $ha^{-1}$) was observed with inoculation of *Azotobacter* + PSB ($B_3$) and lowest net return (60570.90 ` ha^{-1}) was found with no inoculation (B_0). However, treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The net return was increased by 57.36, 46.22 and 87.52 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

4.5.2 B C Ratio

Effect of fertility levels

An appraisal of data in Table 4.19 indicates that B C ratio significantly influenced with increasing levels of fertilizer over control. The significantly maximum B C ratio 100% RDF (3.48) over control and 75% RDF while, it remained at par with 125% RDF (3.28). The data further revealed that the per cent increase in B C ratio was in order of 30.35, 35.79 and 27.62 due to application of 75% RDF (F_1), 100% RDF (F_2) and 125% RDF (F_3) over control (F_0), respectively.

Effect of liquid biofertilizers

Inoculation of seed with different liquid biofertilizers *viz., Azotobacter*, PSB and *Azotobacter* + PSB was significantly influenced the B C ratio over the control. Among the different combination of biofertilizers, *Azotobacter* + PSB (B_3) was recorded maximum B C ratio (3.74). The minimum B C ratio (2.18) was found with no inoculation (B_0) and treatment B_1 (*Azotobacter*) and B_2 (PSB) were found statistically at par. The B C ratio was increased by 59.5, 51.5 and 90 per cent due to application *Azotobacter* (B_1), PSB (B_2) and *Azotobacter* + PSB (B_3) over control (B_0), respectively.

5. DISCUSSION

In the course of presenting the results of the field experiment entitled **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)"** significant variations were observed in number of criteria used for treatment evaluation. In this chapter, an attempt is being made to discuss variations observed significant or assuming a uniform trend to establish the cause and effective relationship *vis-a-vis* existing evidence and literatures.

5.1 EFFECT OF FERTILITY LEVELS

5.1.1 Growth Parameter

The results of the investigation presented in previous chapter (Table 4.1) 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 plant height (30 DAS, 60 DAS and at harvest) were increased by tune of 26, 24.50 and 19.81 due to application of 100% RDF over control, respectively. 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). 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).

Similarly, increased supply of available phosphorus enhances formation of new cells, promotes plant vigour 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); Tiwari and Kumar (2009). Xu *et al.* (2020) reported that Potassium has significant effect on the growth and development of plant roots. Potassium acts as an enzyme activator, plays an

important role in protein synthesis of N and C metabolism, sugar transport and photosynthesis. K in plasma membrane stimulates and controls ATPase to generate acid stimulation, resulted improve cell growth by trigging cell wall loosening and hydrolase activation. Meena and Yadav (2015) reported that Potassium had improved the ability of plant to withstand in extreme conditions. 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).

5.1.2 Yield Attributes and Yield

The results of plant mean (Table 4.1 and 4.2) indicate that the application of different fertility levels significantly improve the yield attributes and yield except harvest index. Application of fertility levels could not have any significant effect on harvest index. Yield and yield attributes *viz.* total tillers metre^{-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 grain, straw and biological yields were increased by 61.82, 31.83 and 43.10 per cent with application of 100% RDF over control, respectively. 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 metre^{-1} row length, effective tillers metre^{-1} row length and test weight) (Kumawat *et al.,* 2013). The grain and straw 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). The significant increase in straw 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 straw 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).

5.1.3 Nutrient Content and Uptake

It is evident from results (Table 4.5 and 4.6) that the application of different fertility levels significant improve the N, P, K, S, Zn, Fe, Mn and Cu content and uptake by grain and straw of wheat. The same nutrient increased to each higher level of fertility up to 100% RDF but it remained at par with 125% RDF. The N, P, K, S, Zn, Fe, Mn and Cu content increase by 7.07, 16.24, 10.75, 15.02, 3.53, 4.12, 5.25 and 3.74 percent in grain and 15.43, 11.76, 8.37, 8.33, 3.09, 2.78, 4.96 and 9.21 per cent in straw with application of 100% RDF over control, respectively. An appraisal of data presented in table 4.7 and 4.14show that uptake of N, P, K,S, Zn, Fe, Mn and Cu increase by74.37, 90.22, 82.19, 89.35, 67.53, 68.49, 70.33 and 67.89 percent by grain and 52.15, 47.29, 43.60, 42.68, 35.92, 35.50, 38.36 and 43.97 per cent by straw with application of 100% RDF over control, respectively. This might be due to adequate amount of NPK nutrient in the rhizosphere which increased root and shoot growth as well as absorption of nutrient from deeper soil layers leading to enhanced translocation to reproductive structure such as seeds and other parts of plant. Availability of adequate amount of nitrogen increases the cation exchange capacity of roots thereby enabling them to absorb more nutrients from the soil. Meena *et al.* (2018) reported that uptake of nutrients by grain and straw increased due to higher availability of nutrients resulting higher yield of grain and straw. Similar result was observed by Sharma *et al.* (2013) and Singh and Singh (2017).

5.1.4 Soil Fertility

The bulk density, particle density, porosity, EC, pH and organic carbon (Table 4.15) of soil after harvest of the crop were not significantly affected by application of different fertility levels. The available nitrogen, phosphorus, potassium and sulphur, zinc, iron, manganese and copper content in soil significantly increased to each higher level of fertility up to 100% RDF but it remained at par with 125% RDF (Table 4.16). The increase in available nitrogen, phosphorus, potassium and sulphur status of soil with application of 100% RDF was 12.88, 20.32, 15.24, 11.41, 9.21, 28.04, 9.53 and 2.52 per cent over control, respectively. Significant increase in available nitrogen might be due to increased activity of nitrogen fixing bacteria leading to greater mineralization of applied and inherent nitrogen (Parmer *et al.,* 1998).

Sharma *et al.* (2013) reported that amount of available phosphorus in soil increased with increase in fertility levels due to less use of applied P by crop resulting enhance phosphorus in soil. Significant increase in available phosphorus might be due to increased activity of microorganism leading to greater mineralization of applied and inherent phosphorus. The abundant amount of potassium could be ascribed to the higher amount of potassium being added by potassium fertilizers. Similar findings were given by Gogoi, (2011) and Abbasi and Tahir (2012).

The dehydrogenase enzyme activity, alkaline phosphate activity, microbial population, soil biomass carbon and soil biomass nitrogen significantly affected by application of fertility levels. The dehydrogenase enzyme activity, alkaline phosphate activity, microbial population, soil biomass carbon and soil biomass nitrogen significantly increased to each higher level of fertility up to 100% RDF but it remained at par with 125% RDF. Bhatt *et al.* (2017) reported that the native pools of soil organic carbon act as a substrate for enzymes which is utilized by microorganisms and their activity increases by adding inorganic nutrient source. Multiplication of microbial population due to increase in levels of fertilizers which might have increased the root biomass, root exudates and ultimately provided the carbon and energy to soil microbes (Geetha Kumari and Shivashankar, 1991). These finding are also reported by Chand *et al.* (2010) and Parewa *et al.* (2014).

5.2 EFFECT OF LIQUID BIOFERTILIZERS

5.2.1 Growth Parameter

It is cleared from the data presented in Table 4.1 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. The plant height (30 DAS, 60 DAS and at harvest) were increase by tune of 22.84, 20.95 and 14.78 due to seed inoculation with *Azotobacter* + PSB over control, respectively. 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) 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) 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). 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).

5.2.2 Yield Attributes and Yield

The results of the investigation presented (Table 4.1 and 4.2) in previous chapter 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. The grain, straw and biological yield were increase by 64.72, 35.49 and 46.59 per cent due to seed inoculation with *Azotobacter* + PSB over control, respectively. Jnawali *et al.* (2015) 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 straw yield (Selvakumar *et al.,* 2012). 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). Combine inoculation of *Azotobacter* + PSB increased straw 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).

5.2.3 Nutrient Content and Uptake

In the present study data revealed that nitrogen, phosphorus, potassium and sulphur content and uptake by grain and stover of wheat significantly increase by inoculation of seed with different liquid biofertilizers. The highest same nutrient was found with combine inoculation of *Azotobacter* + PSB over control and single inoculation. The content of Zn, Fe, Mn and Cu did not increase significantly but uptake increase significantly with combine inoculation of *Azotobacter* + PSB. The N, P, K, and S content increase by 7.35, 17.75, 11.27 and 19.41percent in grain and 16.41, 11.65, 10.22 and 11.80per cent in straw with combine inoculation of *Azotobacter* + PSB over control, respectively. An appraisal of data presented in table (4.7 and 4.14) show that uptake of N, P, K, S, Zn, Fe, Mn and Cu increase by63.93,78.56, 70.77, 80.00, 66.79, 70.63, 69.39 and 66.77percent by grain and 57.78, 51.55, 49.36, 51.52, 37.33, 39.22, 37.11 and 40.22 per cent by straw with combine inoculation of *Azotobacter* + PSB over control, respectively. The mineralization of organic nitrogen and phosphorus increases the availability of nitrogen and phosphorus in soil which have resulted in greater uptake of nutrients by plants by inoculation of nitrogen and phosphorus fixing bacteria. *Azotobacter* enhanced activity of nitrogenage and nitrate reductase enzymes in soil for higher nitrogen fixation. Hameeda *et al.*(2008) reported that insoluble inorganic phosphate compounds such as tricalcium phosphate and dicalcium phosphate in soil solubilize by PSB by excretion of different organic acids from root exudates. Potassium uptake from soil also increases due to increase in availability of N and P. Thus synergistic effect of biofertilizers increased the content and uptake of nitrogen, phosphorus and

potassium in grain and stover. These results are in close conformity with those of Silva *et al.* (2012); Singh *et al.* (2013); Maheshwari and Elakkiya (2014) and Khan *et al.* (2015).

5.2.4 Soil Fertility

The bulk density, particle density, porosity, EC, pH and organic carbon (Table 4.15) of soil after harvest of the crop were not significantly affected by inoculation of seed with different liquid biofertilizers. The available nitrogen, phosphorus, potassium and sulphur content in soil significantly increased by inoculation of seed with different liquid biofertilizers, whereas available zinc, iron, manganese and copper were found non-significant with inoculation of seed with different liquid biofertilizers (Table 4.16). The increase in available nitrogen, phosphorus, potassium and sulphur status of soil with inoculation of seed with different liquid biofertilizers was 9.90, 19.48, 18.23 and 4.53per cent over control, respectively. Organic acids secretion by PSB which can solubilize P from insoluble and fixed forms to plant available forms, whereas conversion of atmosphere nitrogen into plant available form of nitrogen in the soil by *Azotobacter.* Acharya *et al.* (2002) reported that biofertilizers inoculation increased availability of phosphorus in soil might be due to excretions of substances that form complex with cations like Ca, Mg and Al in soil which responsible for fixation.

The dehydrogenase enzyme activity, alkaline phosphate activity, microbial population, soil biomass carbon and soil biomass nitrogen significantly affected by inoculation of seed with different liquid biofertilizers. Soil microbial biomass carbon and nitrogen significantly increased might be due to microbial population increased by secretion of mucigel, sloughed off cells, exudates, roots remain of previous crop etc. The inoculation of biofertilizers increases the biological activities might have enhanced the soil microbial biomass carbon and nitrogen (Behera *et al.,* 2007).Shinde and Bangar (2003) reported that increase in the enzyme activity and microbial population in soil might be due to enhancement in porosity and availability of nutrients especially P to the plant along with better installation of inoculated micro-organism, which stimulates the indigenous microorganism. Microbial inoculation might have increased the population of beneficial microorganism in soil. Similar finding was also given by Nath *et al.* (2011).

6. SUMMARY AND CONCLUSION

Results of field experiment entitled **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)"** was conducted during *rabi* 2019 at Instructional Farm, Rajasthan College of Agriculture, Udaipur situated in the Sub-humid Southern Plain and Aravalli Hills of Rajasthan (Zone IVa) are presented and discussed in the preceding chapters are summarized and concluded below.

6.1 EFFECT OF FERTILITY LEVELS

6.1.1 Growth

Plant height

- Enrichment of soil with 100% RDF significantly increased the plant height at 30 DAS, at 60 DAS and at harvest (44.10, 77.49 and 100.91) of wheat over 75% RDF and control but statistically at par with 125% RDF.
- The maximum plant height was found by seed inoculation with *Azotobacter* + PSB at 30 DAS, at 60 DAS and at harvest (42.86, 76.46 and 99.53) over other treatments.

6.2 YIELD ATTRIBUTES AND YIELD

Total tillers and effective tillers

- Application of 100% RDF being at par with 125% RDF significantly increased the total tillers m^{-1} row length (95.25) and effective tillers m^{-1} row length (76.47) of wheat over 75% RDF and control.
- The maximum total tillers and effective tillers m^{-1} row length (93.51 and 75.10) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Test weight

- Crop fertilized with 100% RDF significantly increased the test weight (43.90 g) of grain over 75% RDF and control but statistically at par with 125% RDF.
- The maximum test weight (43.36 g) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Grain yield

- Application of 100% RDF being at par with 125% RDF significantly increased the grain yield (4917.51 kg ha^{-1}) of wheat over 75% RDF and control.
- The maximum grain yield (5060.26 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Straw yield

- Increasing levels of fertility up to 100% RDF significantly increased the straw yield (6649.19 kg ha^{-1}) over 75% RDF and control but remained at par with 125% RDF.
- The highest straw yield (6801.00 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Biological yield

- Application of 100% RDF being at par with 125% RDF significantly increased the grain yield (11566.70 kg ha^{-1}) of wheat over 75% RDF and control.
- The highest biological yield (11861.26 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Harvest index

- Harvest index could not vary significantly with fertility levels and biofertilizers inoculation.

6.3 NUTRIENT CONTENT

Nitrogen content

- Nitrogen content in grain and straw significantly influenced to each higher level of fertility up to 100% RDF (1.516 and 0.531%) but it remained at par with 125% RDF.
- The highest nitrogen content in grain and straw (1.518 and 0.532%) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Phosphorus content

- Increasing levels of fertility up to 100% RDF significantly increased the phosphorus content in grain and straw (0.322 and 0.209%) over 75% RDF and control but remained at par with 125% RDF.
- The highest phosphorus content in grain as well as straw (0.325 and 0.208%) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Potassium content

- Application of 100% RDF being at par with 125% RDF significantly increased the potassium content in grain and straw (0.535 and 1.465%) over 75% RDF and control.
- The highest potassium content in grain as well as straw (0.538 and 1.466%) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Sulphur content

- Enrichment of soil with 100% RDF significantly increased the sulphur content in grain as well as in straw (0.199 and 0.157%) over 75% RDF and control but statistically at par with 125% RDF.
- The highest sulphur content in grain as well as straw (0.203 and 0.161%) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Zinc content

- Application of 100% RDF being at par with 125% RDF significantly increased the zinc content in grain and straw (26.92 and 13.64 mg kg^{-1}) over 75% RDF and control.
- Zinc content in grain and straw could not influence significantly with biofertilizers inoculation.

Iron content

- Increasing levels of fertility up to 100% RDF significantly increased the iron content in grain and straw (75.91 and 148.66 mg kg^{-1}) over 75% RDF and control but remained at par with 125% RDF.
- Iron content in grain and straw could not influence significantly with biofertilizers inoculation.

Manganese content

- Enrichment of soil with 100% RDF significantly increased the manganese content in grain as well as in straw (13.95 and 22.32 mg kg^{-1}) over 75% RDF and control but statistically at par with 125% RDF.
- Manganese content in grain and straw could not influence significantly with biofertilizers inoculation.

Copper content

- Application of 100% RDF being at par with 125% RDF significantly increased the copper content in grain and straw (7.86 and 3.64 mg kg^{-1}) over 75% RDF and control.
- Copper content in grain and straw could not influence significantly with biofertilizers inoculation.

6.4 NUTRIENT UPTAKE

Nitrogen uptake

- Nitrogen uptake by grain and straw significantly increased to each higher level of fertility up to 100% RDF (74.54 and 35.30 kg ha^{-1}) but it remained at par with 125% RDF.
- The highest nitrogen uptake in grain as well as straw (76.81 and 36.18 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Phosphorus uptake

- Application of 100% RDF being at par with 125% RDF significantly increased the phosphorus uptake by grain and straw (15.83 and 13.89 kg ha^{-1}) over 75% RDF and control.
- The highest phosphorus uptake in grain as well as straw (16.44 and 14.14 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Potassium uptake

- Increasing levels of fertility up to 100% RDF significantly increased the potassium uptake in grain and straw (26.30 and 97.41 kg ha^{-1}) over 75% RDF and control but remained at par with 125% RDF.

- The highest potassium uptake in grain as well as straw (27.22 and 99.70 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Sulphur uptake

- Sulphur uptake by grain and straw significantly increased to each higher level of fertility up to 100% RDF (9.78 and 10.43 kg ha^{-1}) but it remained at par with 125% RDF.
- The highest sulphur uptake in grain as well as straw (10.27 and 10.94 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Zinc uptake

- Application of 100% RDF being at par with 125% RDF significantly increased the zinc uptake by grain and straw (132.37 and 90.69 g ha^{-1}) over 75% RDF and control.
- The highest zinc uptake in grain as well as straw (133.94 and 91.33g ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Iron uptake

- Iron uptake by grain and straw significantly increased to each higher level of fertility up to 100% RDF (373.31and 988.46g ha^{-1}) but it remained at par with 125% RDF.
- The highest iron uptake in grain as well as straw (382.42 and 1012.28 g ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Manganese uptake

- Increasing levels of fertility up to 100% RDF significantly increased the manganese uptake in grain and stover (68.61and 148.40g ha^{-1}) over 75% RDF and control but remained at par with 125% RDF.
- The highest manganese uptake in grain as well as straw (70.28 and 147.60 g ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Copper uptake

- Application of 100% RDF being at par with 125% RDF significantly increased the copper uptake by grain and straw (38.65and24.26g ha^{-1}) over 75% RDF and control.
- The highest copper uptake in grain as well as straw (39.41and 23.81g ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

6.5 SOIL FERTILITY AFTER HARVEST OF WHEAT

Physico-chemical properties

- Application of fertility levels and biofertilizers inoculation have not significant effect on soil pH, EC, organic carbon, bulk density, particle density and porosity of soil after harvest of wheat.

Available nitrogen

- Application of 100% RDF being at par with 125% RDF significantly increased the available nitrogen (305.10 kg ha^{-1}) in soil after crop harvest over 75% RDF and control.
- The highest available nitrogen in soil (303.73 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Available phosphorus

- Increasing levels of fertility up to 100% RDF significantly increased the available phosphorus in soil (25.28 kg ha^{-1}) over 75% RDF and control but remained at par with 125% RDF.
- The highest available phosphorus in soil (25.20 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Available potassium

- Application of 100% RDF being at par with 125% RDF significantly increased the available potassium (445.80 kg ha^{-1}) in soil after crop harvest over 75% RDF and control.
- The highest available potassium in soil (447.08 kg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Available sulphur

- Increasing levels of fertility up to 100% RDF significantly increased the available sulphur in soil (10.16 mg ha^{-1}) over 75% RDF and control but remained at par with 125% RDF.
- The highest available sulphur in soil (9.92 mg ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Available zinc

- Increasing levels of fertility up to 100% RDF significantly increased the available zinc in soil (0.73 mg ha^{-1}) over 75% RDF and control but remained at par with 125% RDF.
- Available zinc in soil could not influence significantly with biofertilizers inoculation.

Available iron

- Application of 100% RDF being at par with 125% RDF significantly increased the available iron (5.57 mg ha^{-1}) in soil after crop harvest over 75% RDF and control.
- Available iron in soil could not influence significantly with biofertilizers inoculation.

Available manganese

- Increasing levels of fertility up to 100% RDF significantly increased the available manganese in soil (9.76 mg ha^{-1}) over 75% RDF and control but remained at par with 125% RDF.
- Available manganese in soil could not influence significantly with biofertilizers inoculation.

Available copper

- Application of 100% RDF being at par with 125% RDF significantly increased the available copper (2.10 mg ha^{-1}) in soil after crop harvest over 75% RDF and control.
- Available copper in soil could not influence significantly with biofertilizers inoculation.

Microbial population

- Increasing levels of fertility up to 100% RDF significantly increased the microbial population *viz*. bacterial, fungal and actinomycetes in soil after crop harvest (73.62× 10^7cfu g^{-1} of soil, 25.42 × 10^5cfu g^{-1} of soil and 40.66× 10^6cfu g^{-1} of soil) over 75% RDF and control but remained at par with 125% RDF.
- The highest microbial population *viz*. bacterial, fungal and actinomycetes in soil after harvest (75.88 × 10^7cfu g^{-1} of soil, 27.33 × 10^5cfu g^{-1} of soil and 41.61 × 10^6cfu g^{-1} of soil)was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Soil microbial biomass carbon and nitrogen

- Application of 100% RDF being at par with 125% RDF significantly increased the soil microbial biomass carbon and nitrogen (185.70 and 27.88 mg kg^{-1}) in soil after crop harvest over 75% RDF and control.
- The highest soil microbial biomass carbon and nitrogen (189.48 and 29.18 mg kg^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

Enzyme activity

- Increasing levels of fertility up to 100% RDF significantly increased the dehydrogenase and alkaline phosphate activities (13.53 µg TPF g^{-1} 24 h^{-1} and 20.21 µg PNP g^{-1} ha^{-1}) over 75% RDF and control but remained at par with 125% RDF.
- The highest dehydrogenase and alkaline phosphate activities (13.91µg TPF g^{-1} 24 $h^{-1}$and 21.61 µg PNP g^{-1} ha^{-1}) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

6.6 ECONOMICS

Net return

- The highest net return and B C ratio (99341.18 ` $ha^{-1}$and 3.48) were with 100% RDF but it remained at par with 125% RDF over 75% RDF and control.
- The highest net return and B C ratio (102675.54 ` ha^{-1} and 3.74) was found by seed inoculation with *Azotobacter* + PSB over other treatments.

CONCLUSION

On the basis of results emanated from the present investigation conducted during *rabi* 2019-20, it is concluded that

1. The application 100% RDF proved beneficial to significantly increased the growth, grain yield (4917.51 kg ha^{-1}), stover yield (6649.19 kg ha^{-1}), nutrient content and their uptake, soil properties, net return (99341.18 ` ha^{-1}) and B C ratio (3.48).
2. Among different combination of liquid biofertilizers, seed inoculation with *Azotobacter* + PSB proved to be the most suitable practices which gave significantly maximum growth, grain yield (5060.26 kg ha^{-1}), stover yield (6801.00 kg ha^{-1}), nutrient content and their uptake, soil properties, net return (102675.54 ` ha^{-1}) and B C ratio (3.74).

RECOMMENDATION

On the basis of findings, the it is concluded that 100% RDF + *Azotobacter* + PSB in wheat found significant in term of growth, yield, nutrient content and uptake, nutrient concentration in soil and microbial activities of soil. Highest net return and B C ratio also found with these treatments. 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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Effect of Fertility Levels and Liquid Biofertilizers on Productivity of Wheat (*Triticum aestivum* L.)

Hansa Kumawat* Research Scholar

Dr. D. P. Singh** Major Advisor

ABSTRACT

A field experiment entitled **"Effect of Fertility Levels and Liquid Biofertilizers on Productivity 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 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.

Results showed that enrichment of soil with 100% RDF significantly increased the plant height, total tillersm^{-1} row length, effective tillers m^{-1} row length, test weight, grain, straw and biological yield, nutrient content and uptake by grain and straw *viz.* nitrogen, phosphorus, potassium, sulphur, zinc, iron, manganese and copper, available nitrogen, phosphorus, potassium and sulphur in soil, soil microbial population (bacteria, fungi and actinomycetes), soil microbial biomass carbon and nitrogen, dehydrogenase activity and alkaline phosphatase activity in soil after harvest of wheat.

The significant increase in plant height, total tillersm^{-1} row length, effective tillers m^{-1} row length, test weight, grain, straw and biological yield, nutrient content *viz.* nitrogen, phosphorus, potassium, sulphur in grain and straw, nutrient uptake *viz.* nitrogen, phosphorus, potassium, sulphur, zinc, iron, manganese and copper by grain and straw, available nitrogen, phosphorus, potassium and sulphur in soil, soil microbial population (bacteria, fungi and actinomycetes), soil microbial biomass carbon and nitrogen, dehydrogenase activity and alkaline phosphatase activity in soil after harvest of wheat was observed due to seed inoculation with *Azotobacter* + PSB.

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There was no significant difference was observed due to fertility levels and biofertilizers on harvest index, bulk density, particle density, porosity, soil pH, EC and organic carbon. The liquid biofertilizers failed to show any significant effect on available zinc, iron, manganese and copper content in grain and straw, available zinc, iron, manganese and copper in soil after harvest of wheat.

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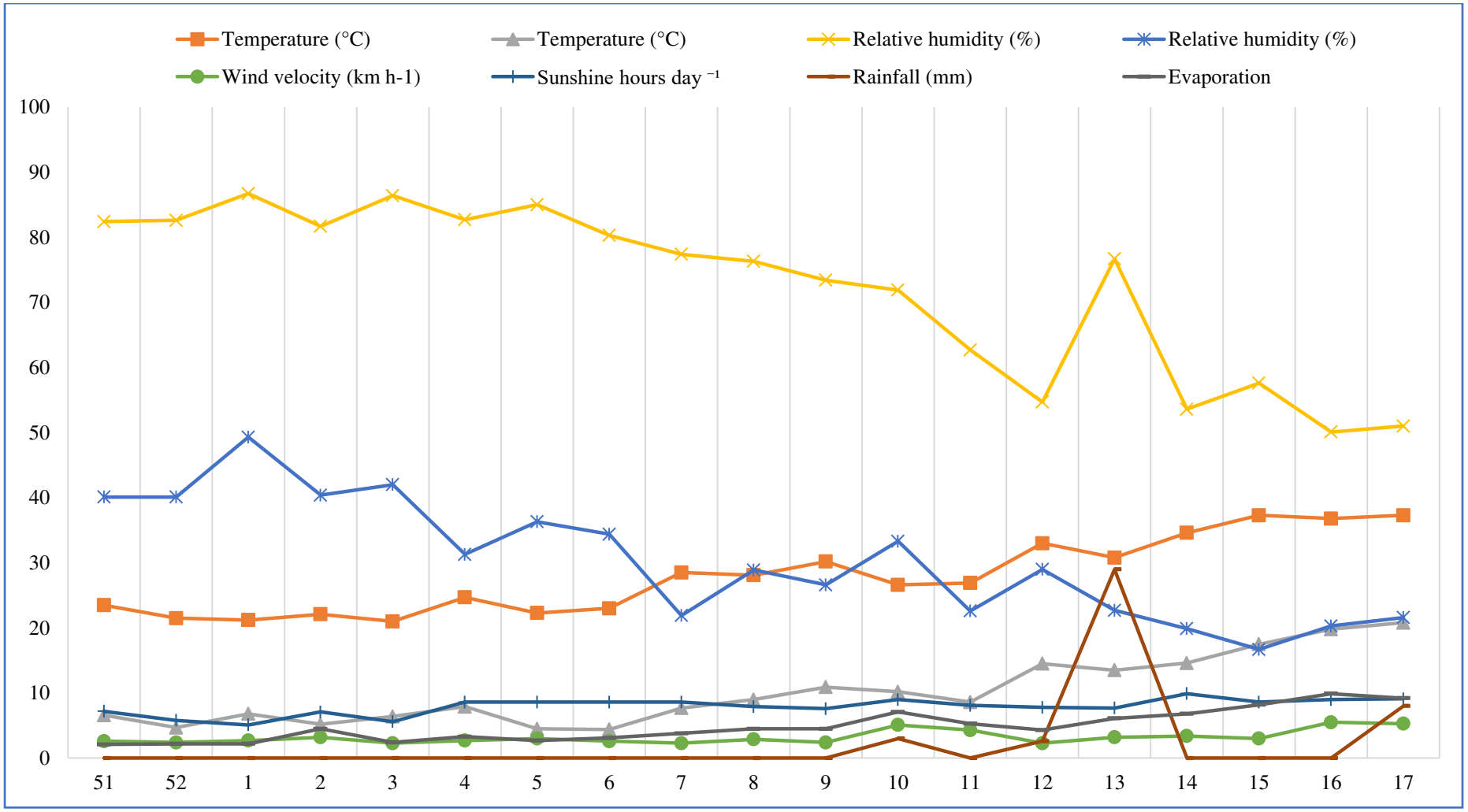


Fig. 3.1: Mean weekly weather parameters for crop season (*Rabi*, 2019-20)

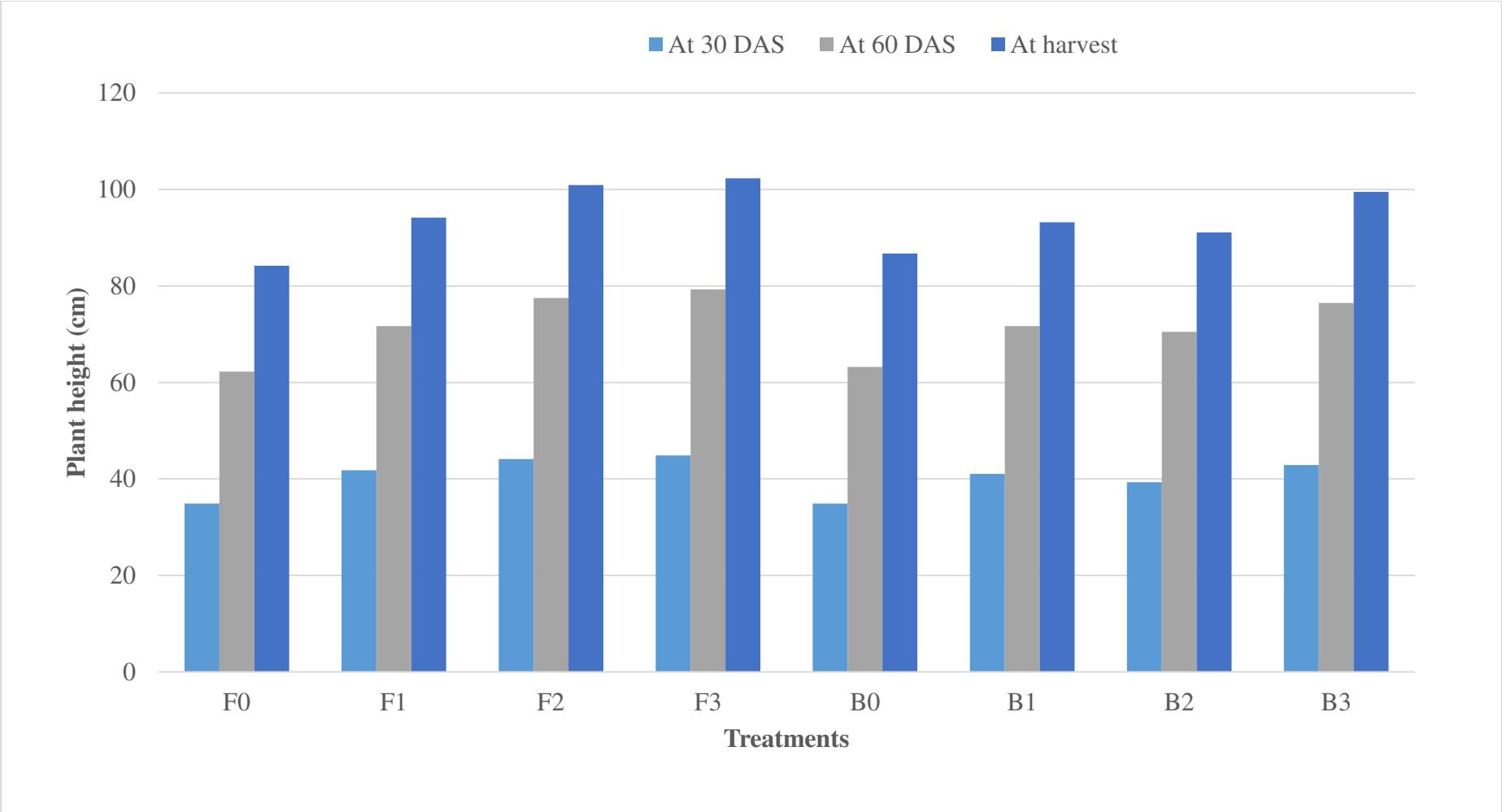


Fig. 4.1: Effect of fertility levels and liquid biofertilizers on plant height of wheat

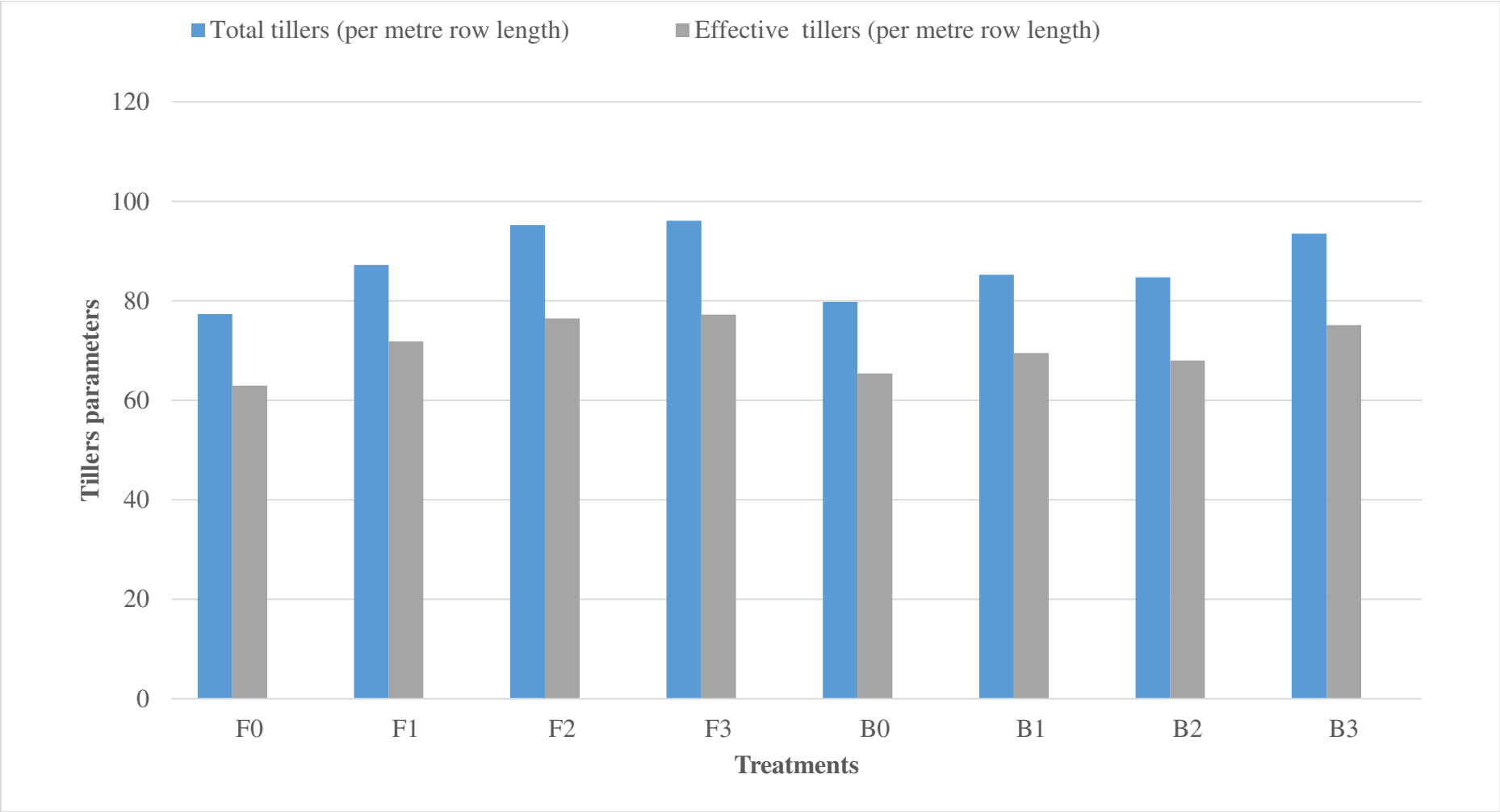


Fig. 4.2: Effect of fertility levels and liquid biofertilizers on total tillers and effective tillers of wheat

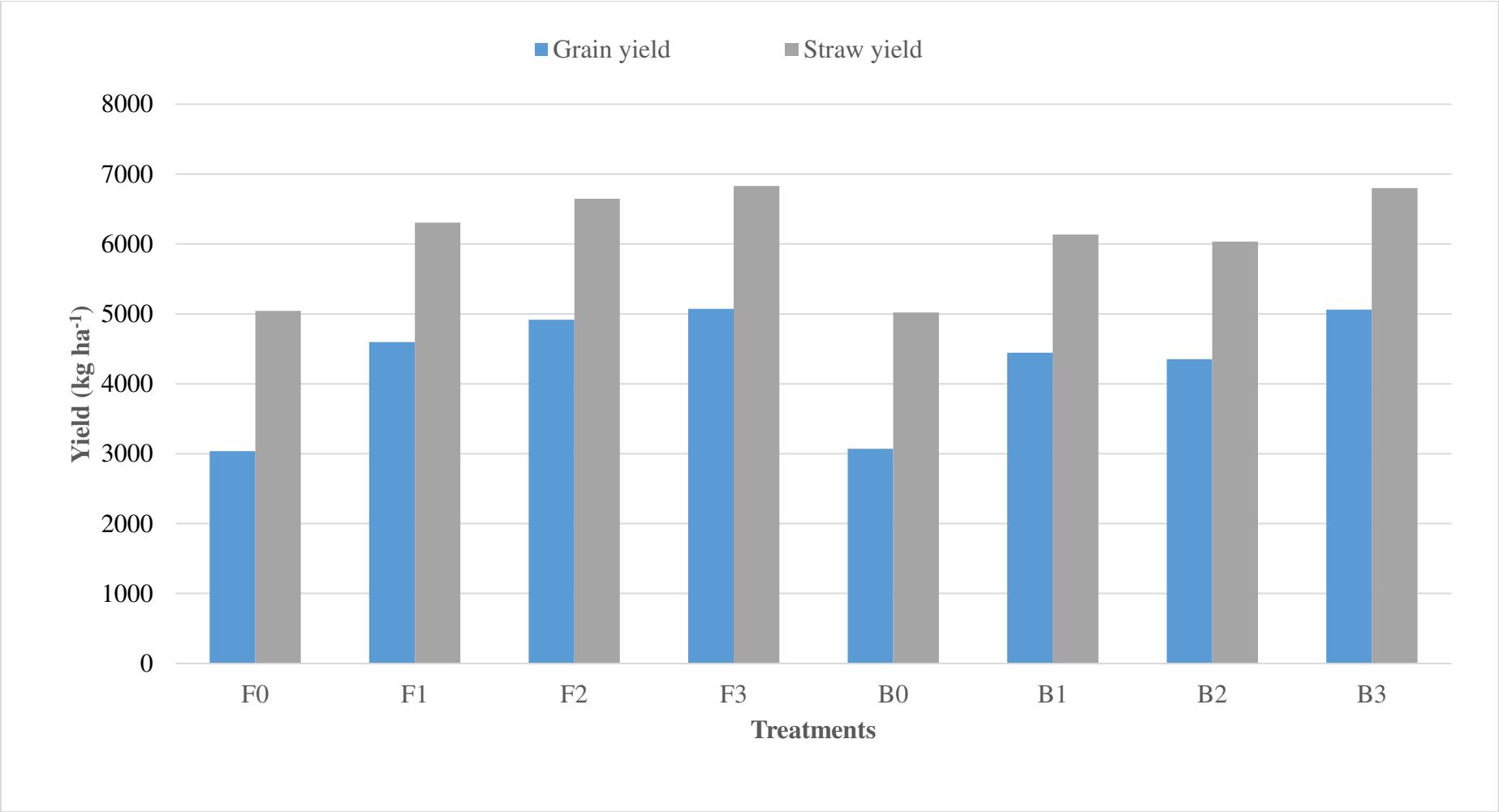


Fig. 4.3: Effect of fertility levels and liquid biofertilizers on grain yield and straw yield of wheat

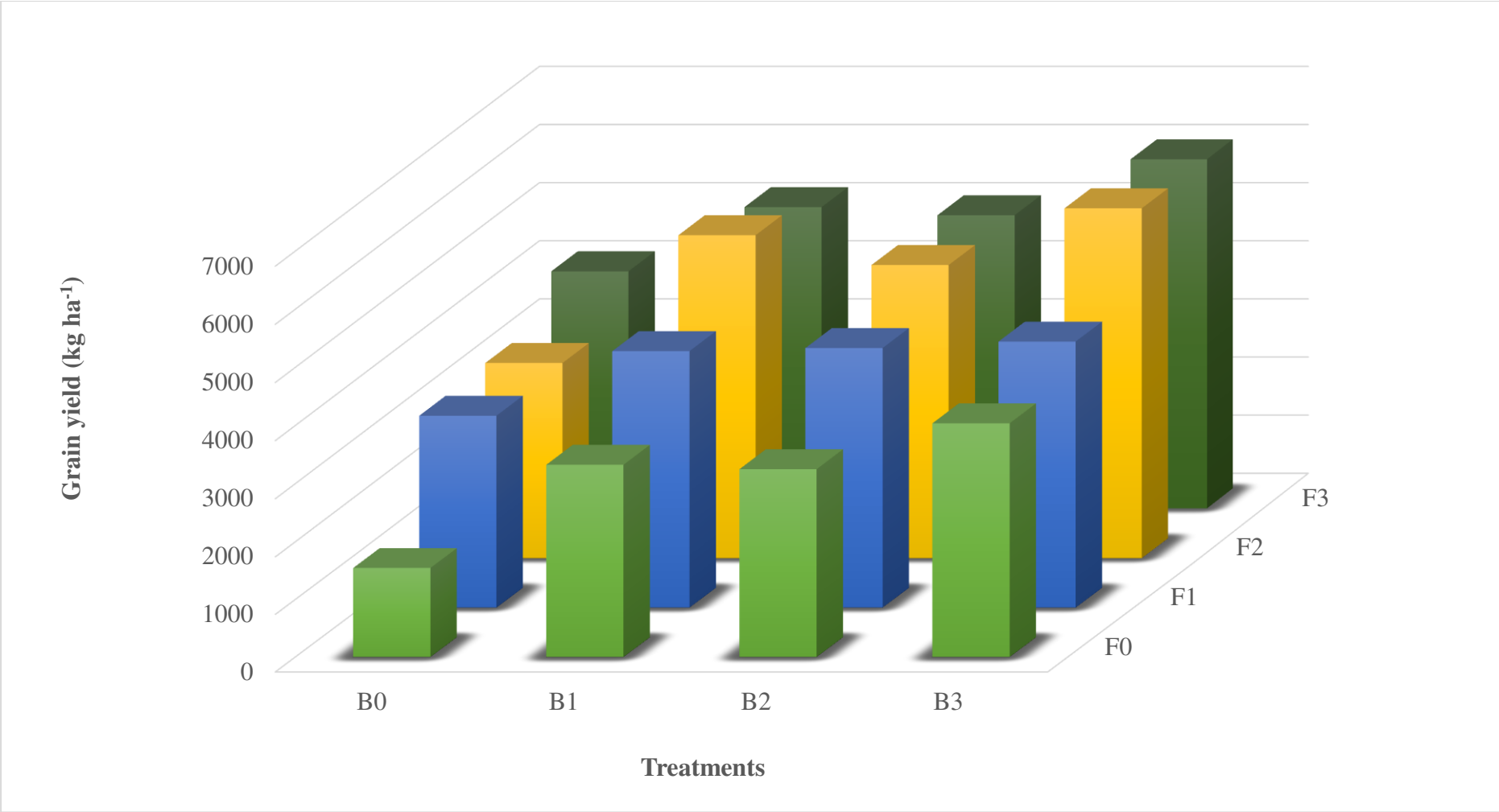


Fig. 4.4: Interaction effect of fertility levels and liquid biofertilizers on grain yieldof wheat

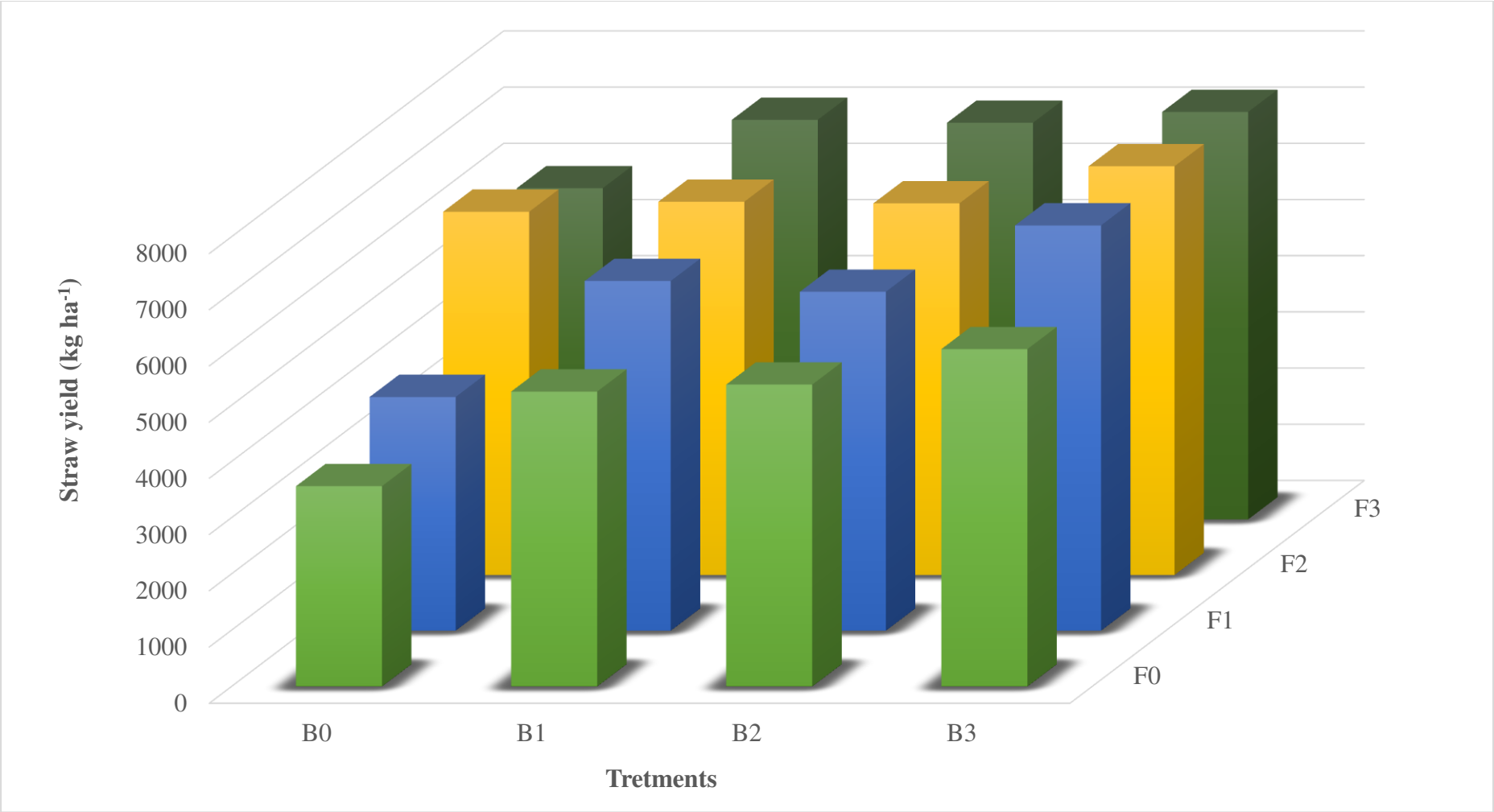


Fig. 4.5: Interaction effect of fertility levels and liquid biofertilizers on straw yield of wheat

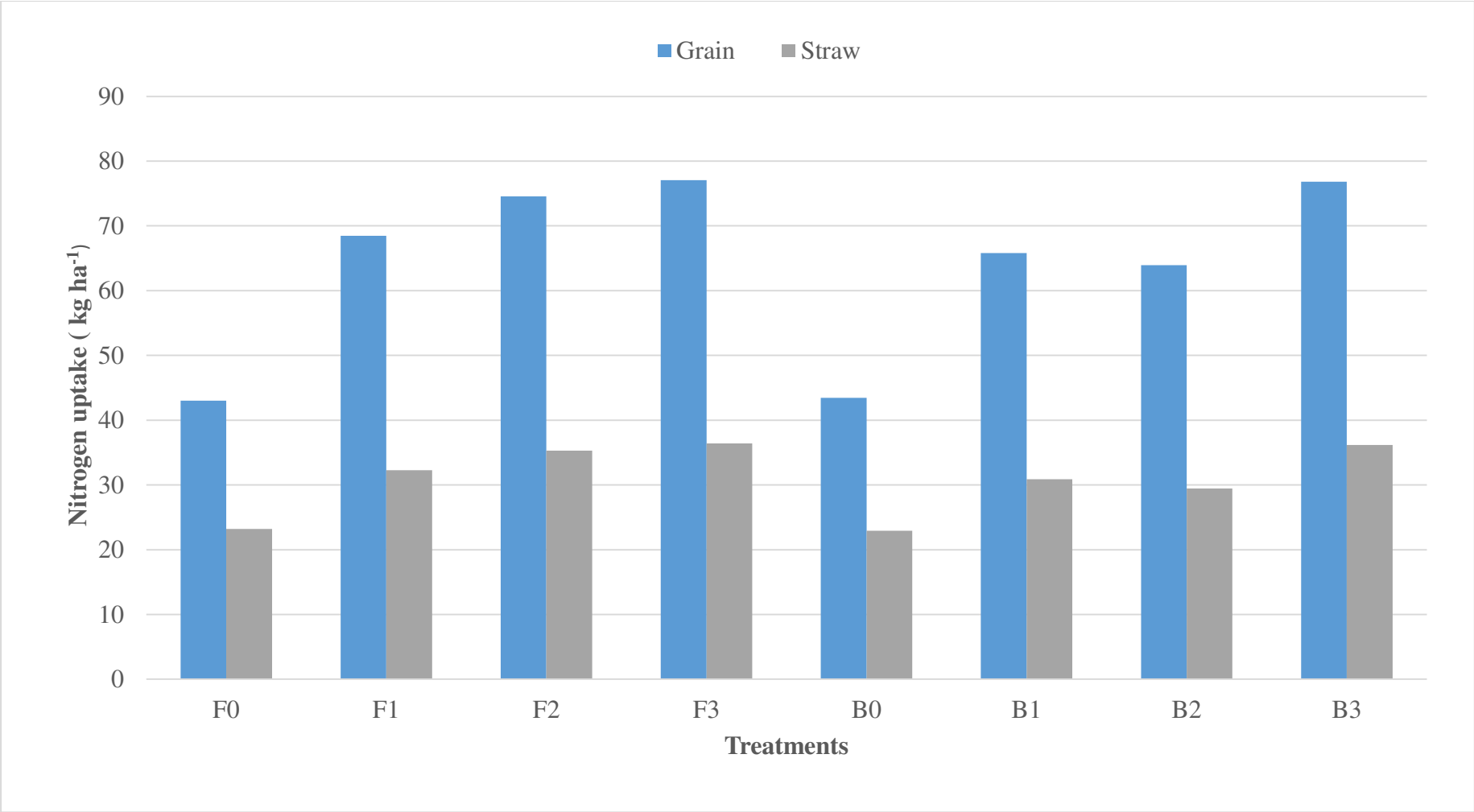


Fig. 4.6: Effect of fertility levels and liquid biofertilizers on nitrogen uptake by wheat

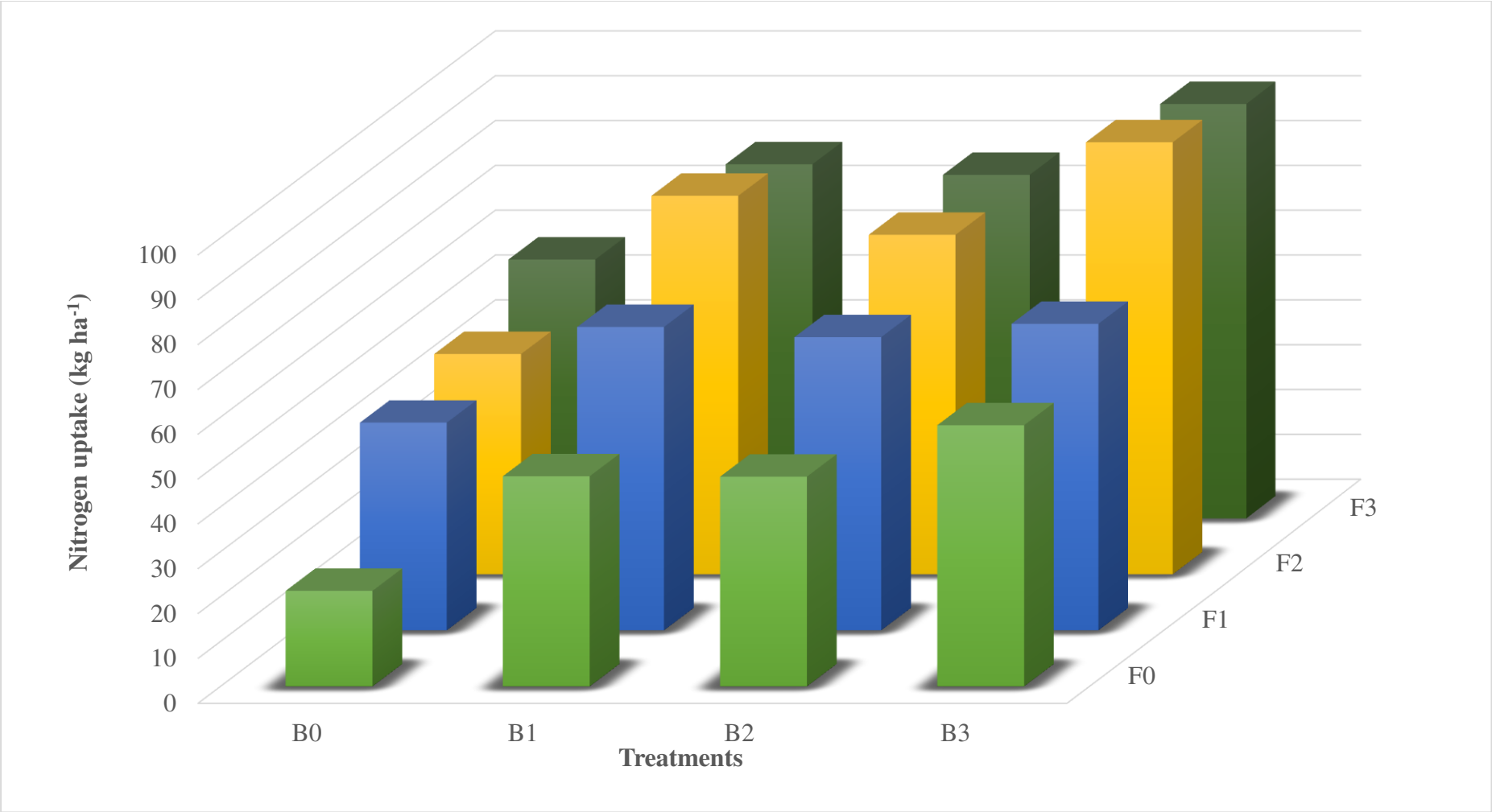


Fig. 4.7: Interaction effect of fertility levels and liquid biofertilizers on nitrogen uptake by grain of wheat

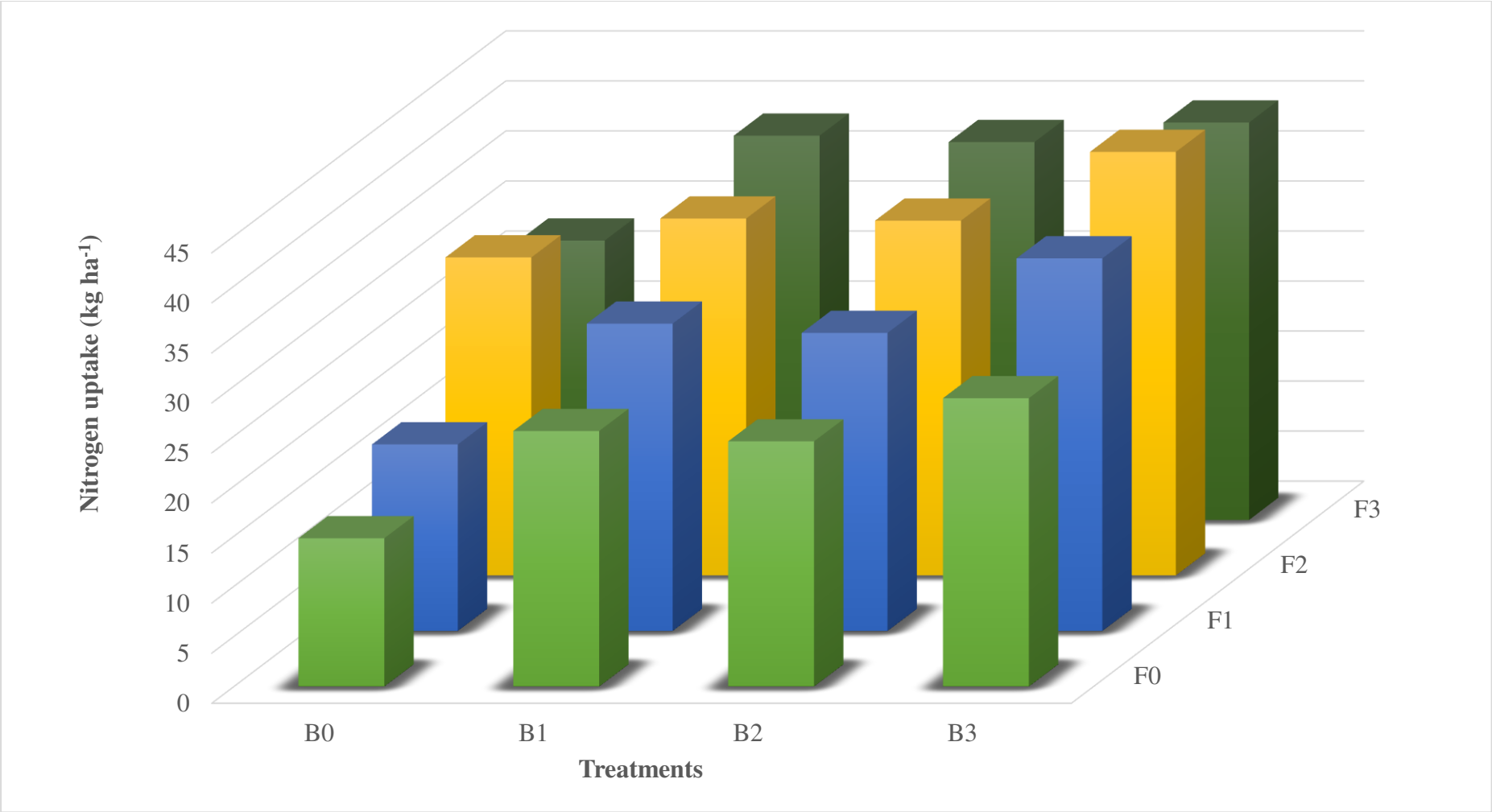


Fig. 4.8: Interaction effect of fertility levels and liquid biofertilizers on nitrogen uptake by straw of wheat

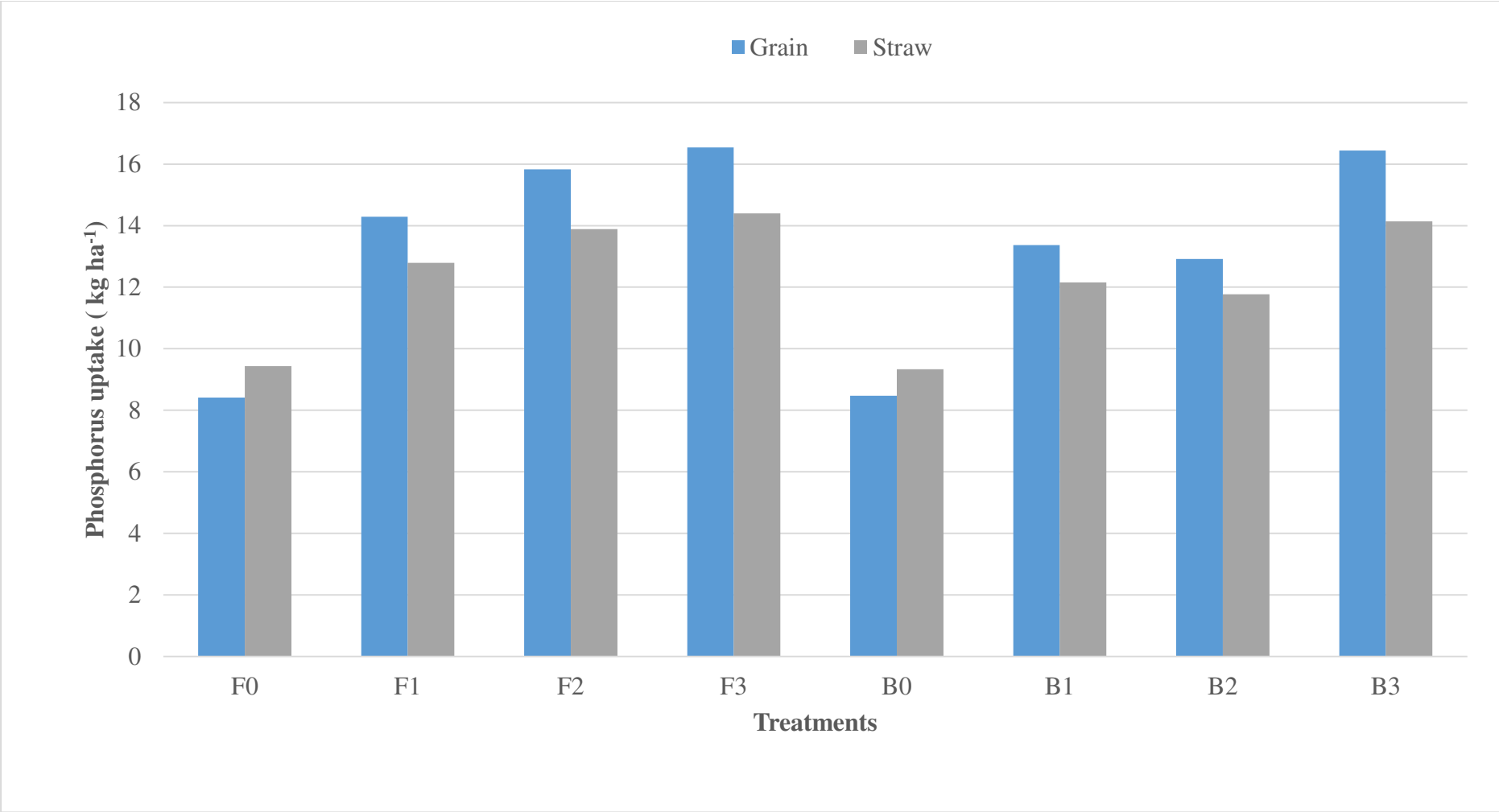


Fig. 4.9: Effect of fertility levels and liquid biofertilizers on phosphorus uptake by wheat

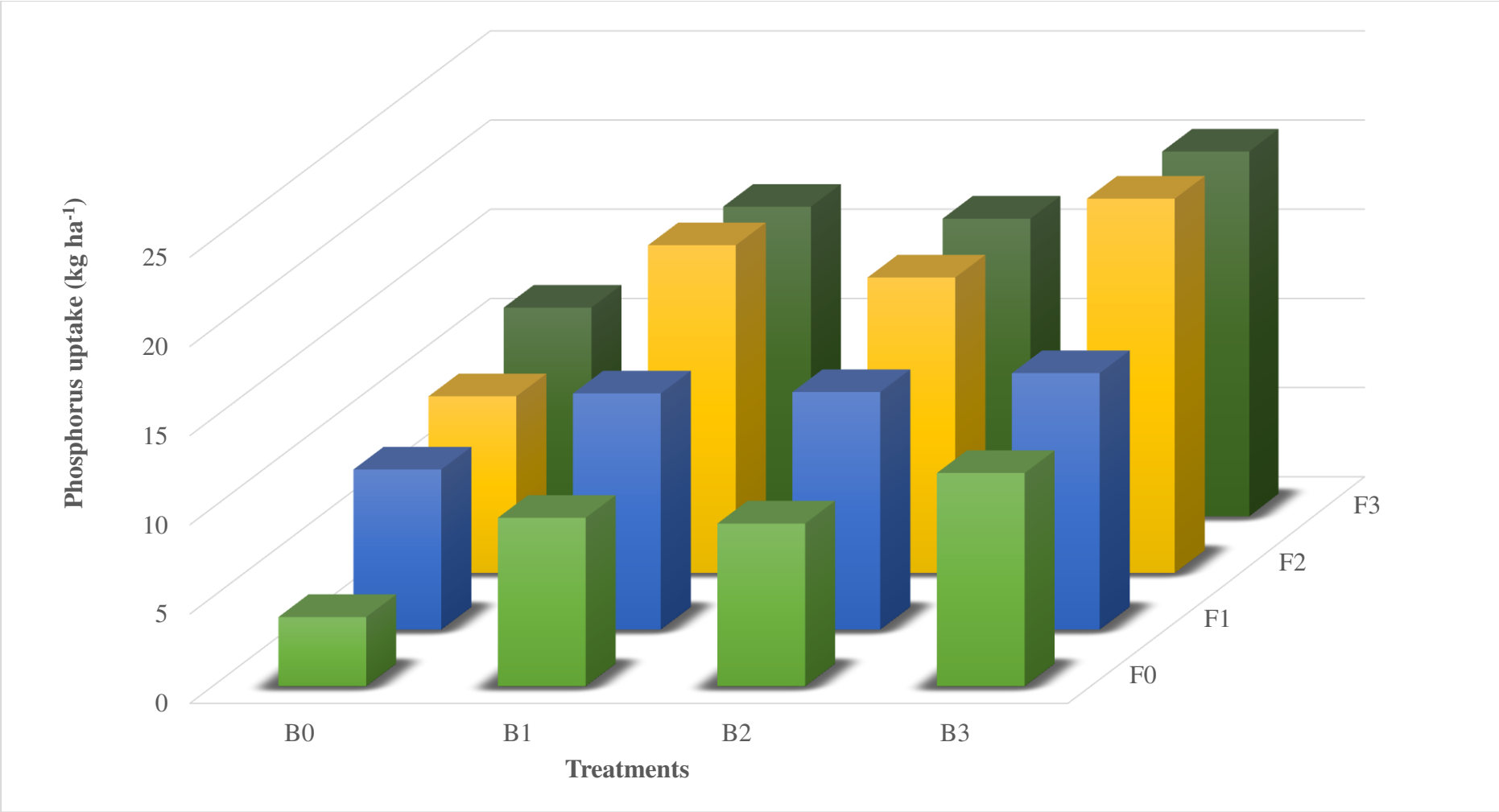


Fig. 4.10: Interaction effect of fertility levels and liquid biofertilizers on phosphorus uptake by grain of wheat

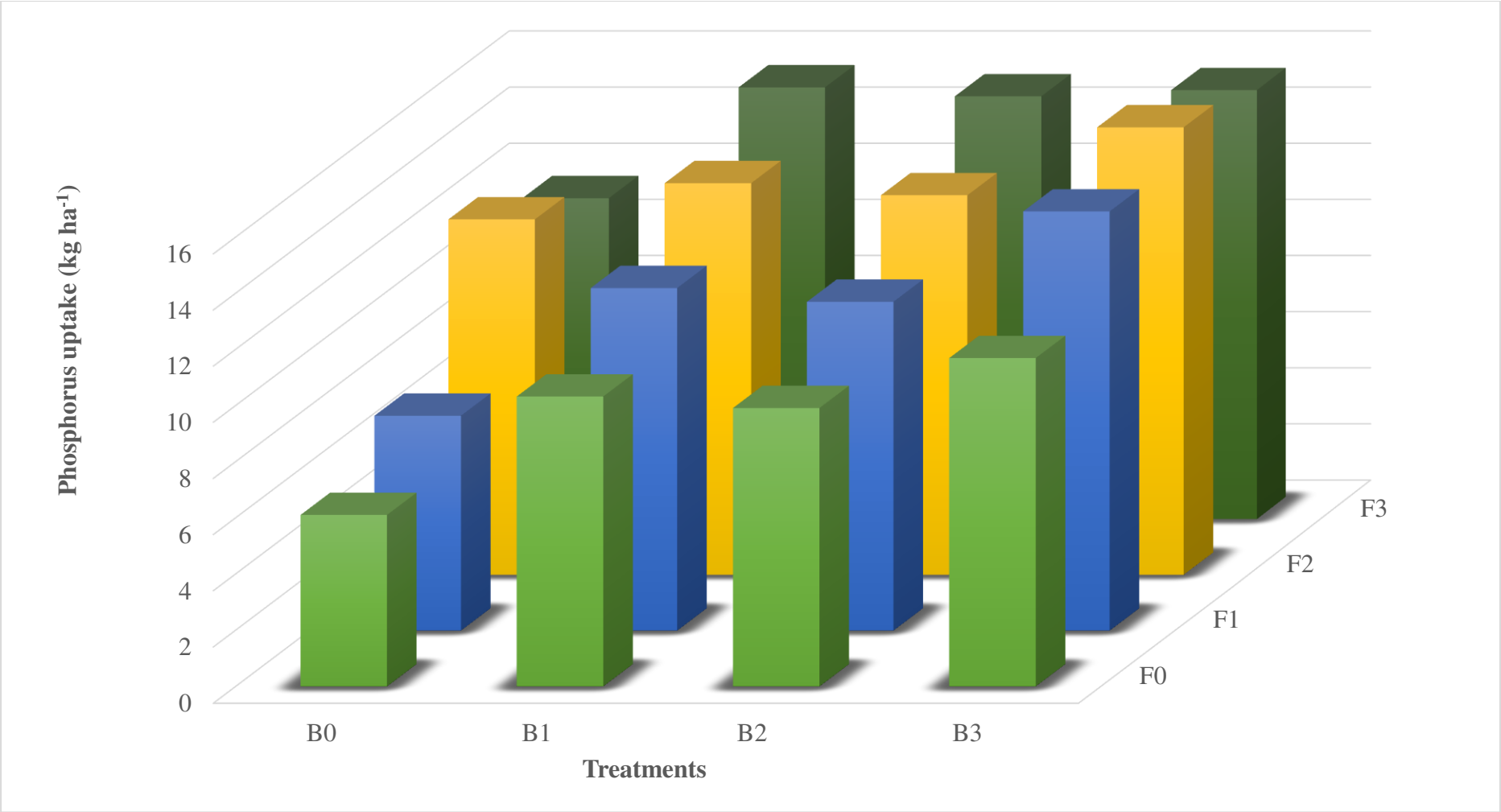


Fig. 4.11: Interaction effect of fertility levels and liquid biofertilizers on phosphorus uptake by strawof wheat

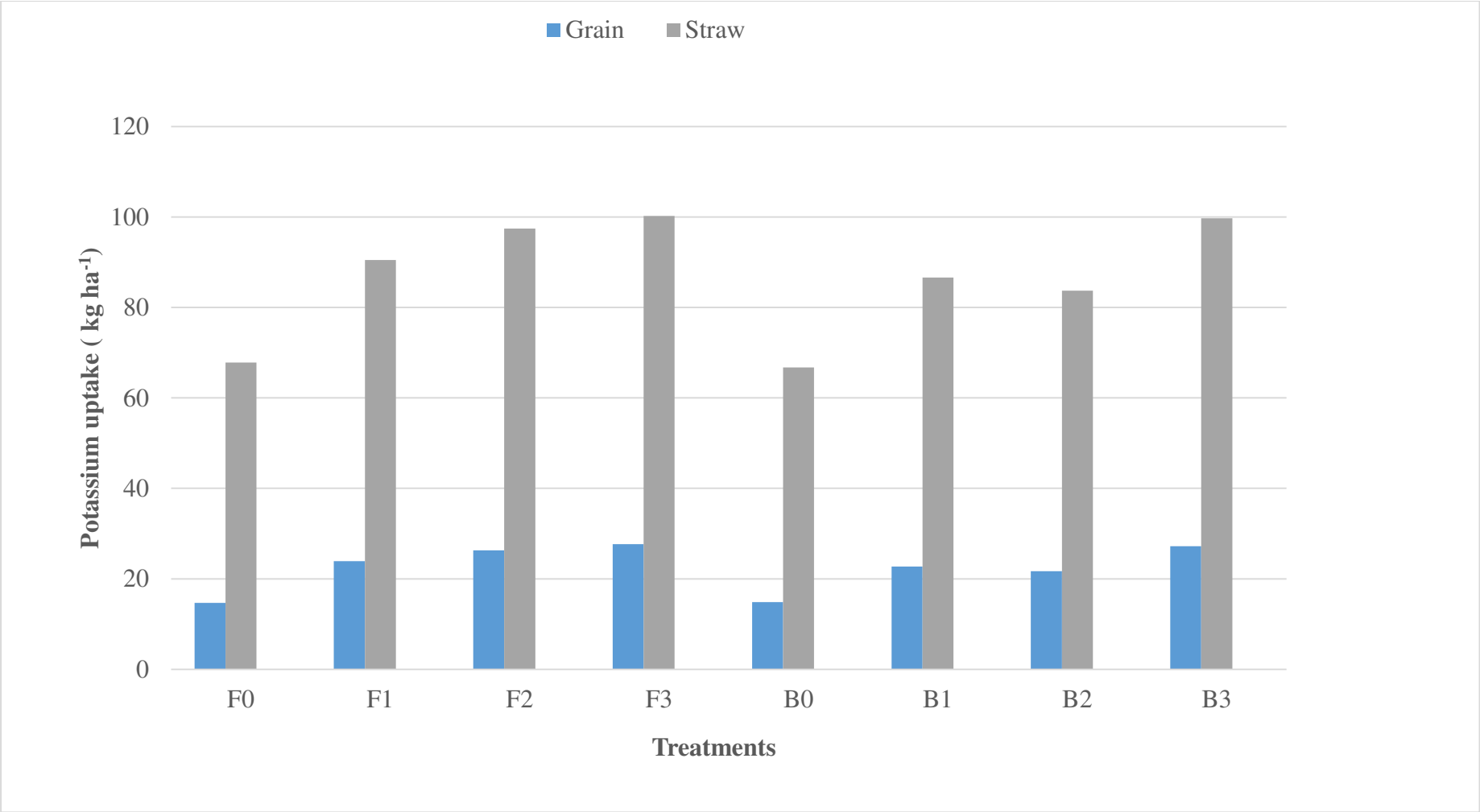


Fig. 4.12: Effect of fertility levels and liquid biofertilizers on potassium uptake by wheat

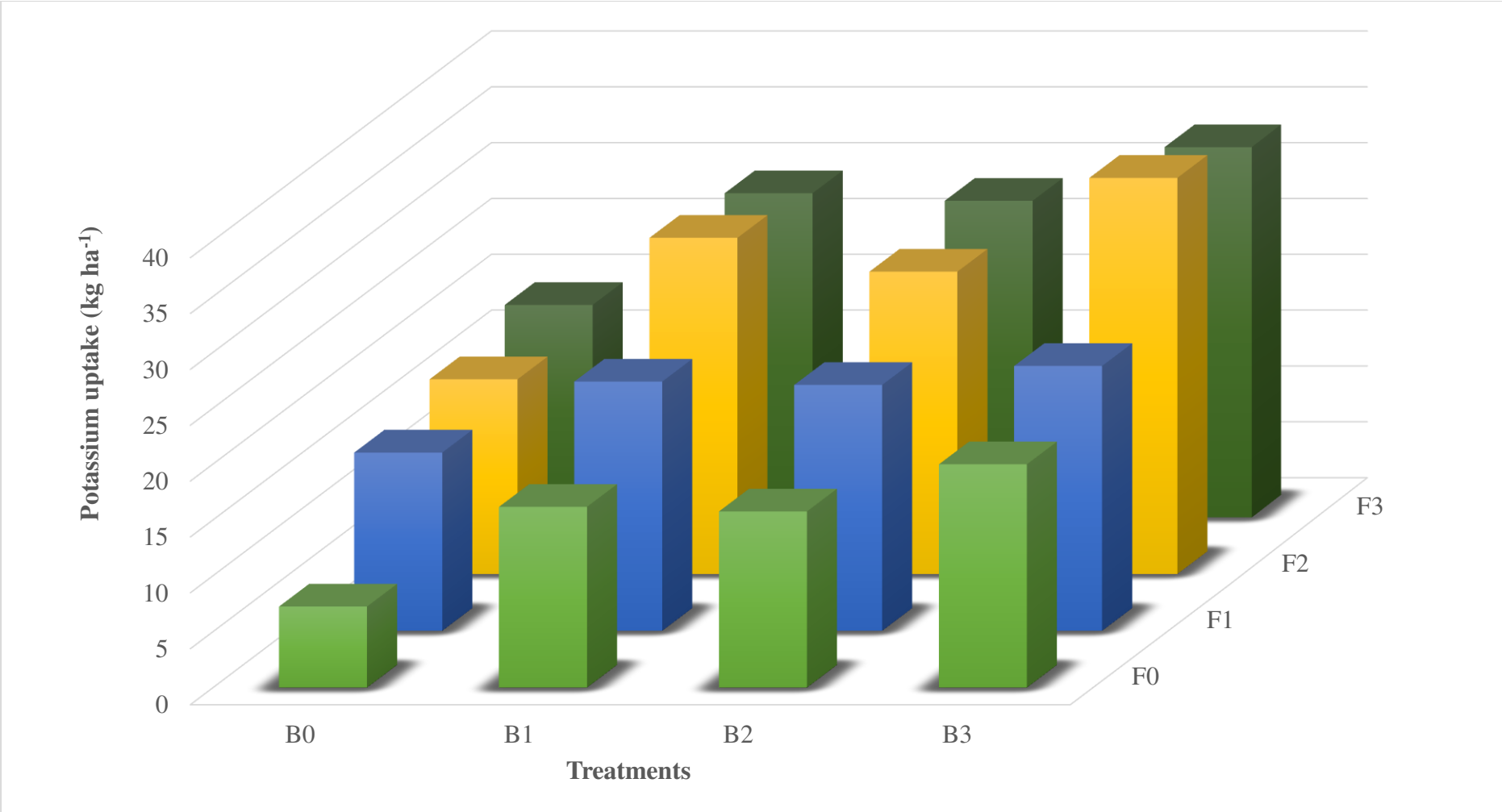


Fig. 4.13: Interaction effect of fertility levels and liquid biofertilizers on potassium uptakeby grain of wheat

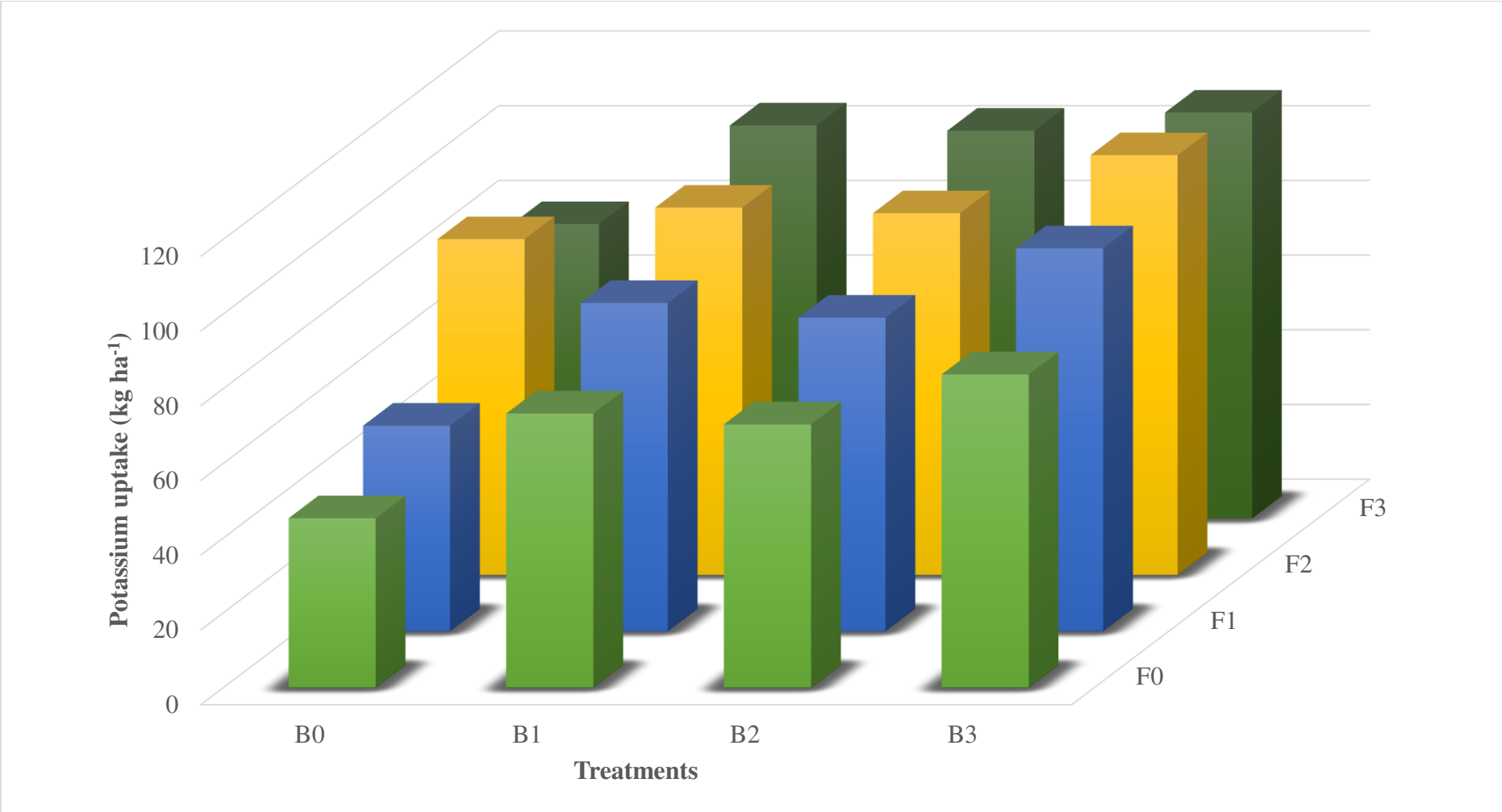


Fig. 4.14: Interaction effect of fertility levels and liquid biofertilizers on potassium uptakeby straw of wheat

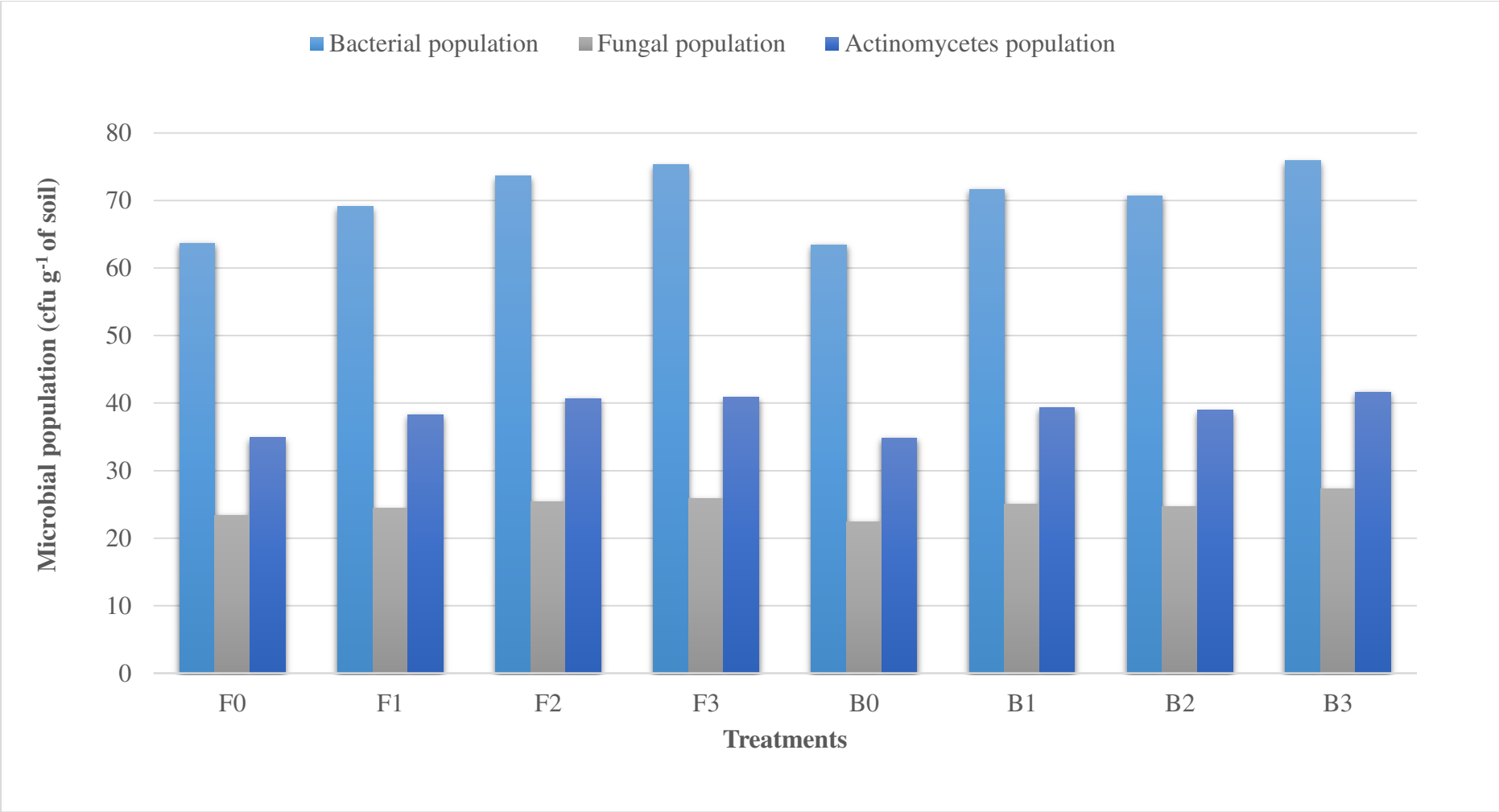


Fig. 4.15: Effect of fertility levels and liquid biofertilizers on microbial population in soil after crop harvest

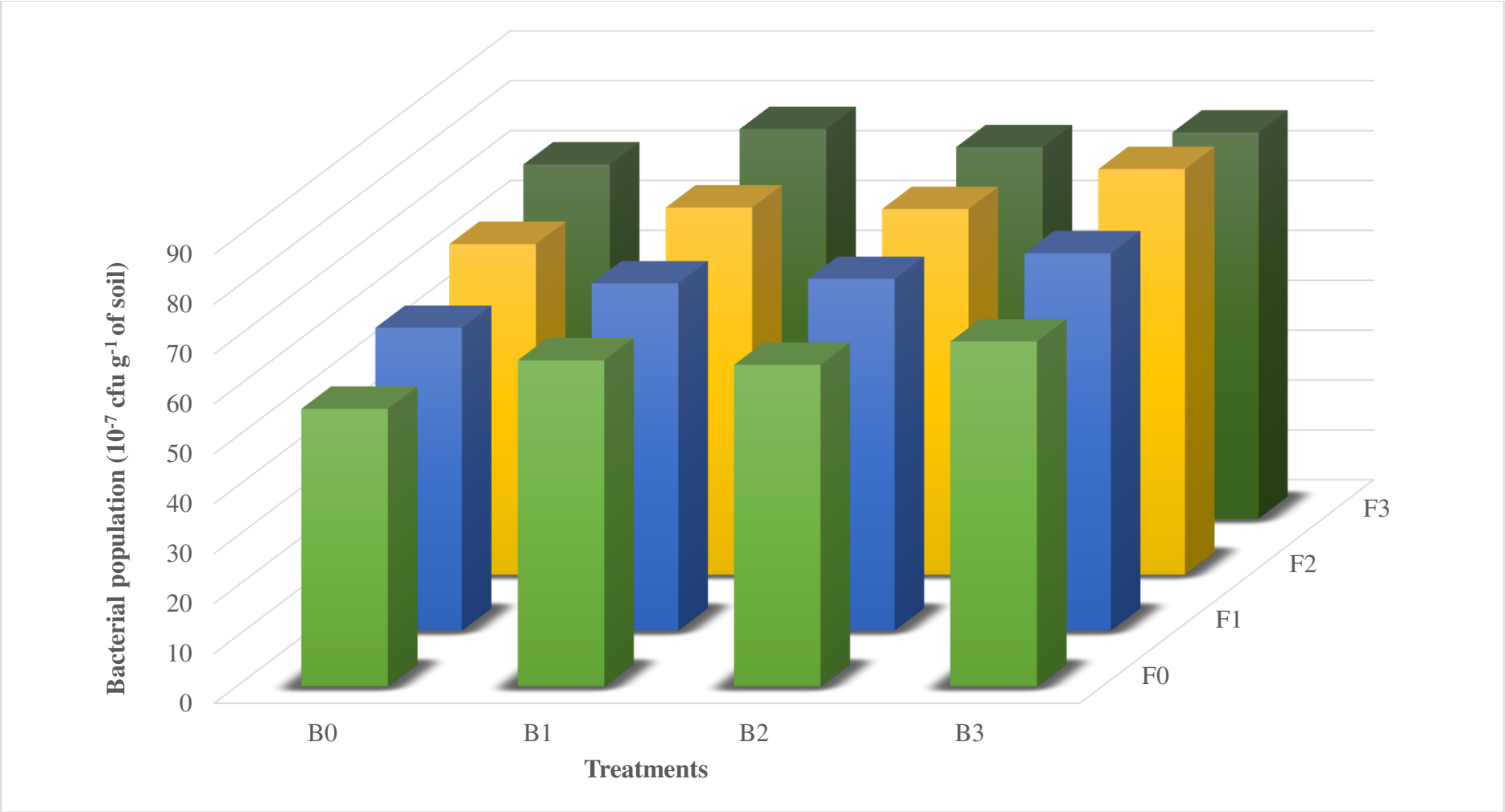


Fig. 4.16: Interaction effect of fertility levels and liquid biofertilizers on bacterial population

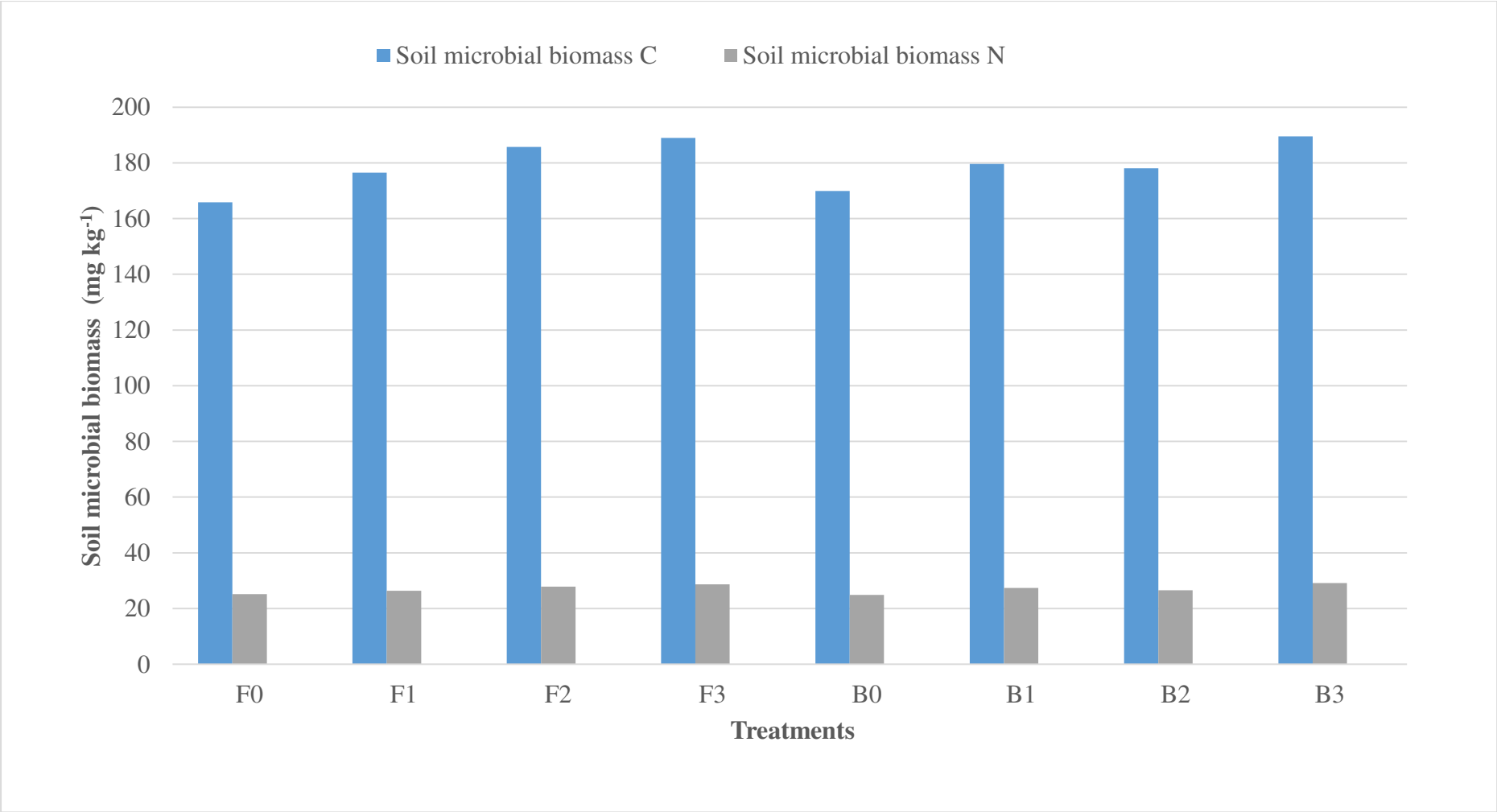


Fig. 4.17: Effect of fertility levels and liquid biofertilizers on soil microbial biomass in soil after crop harvest

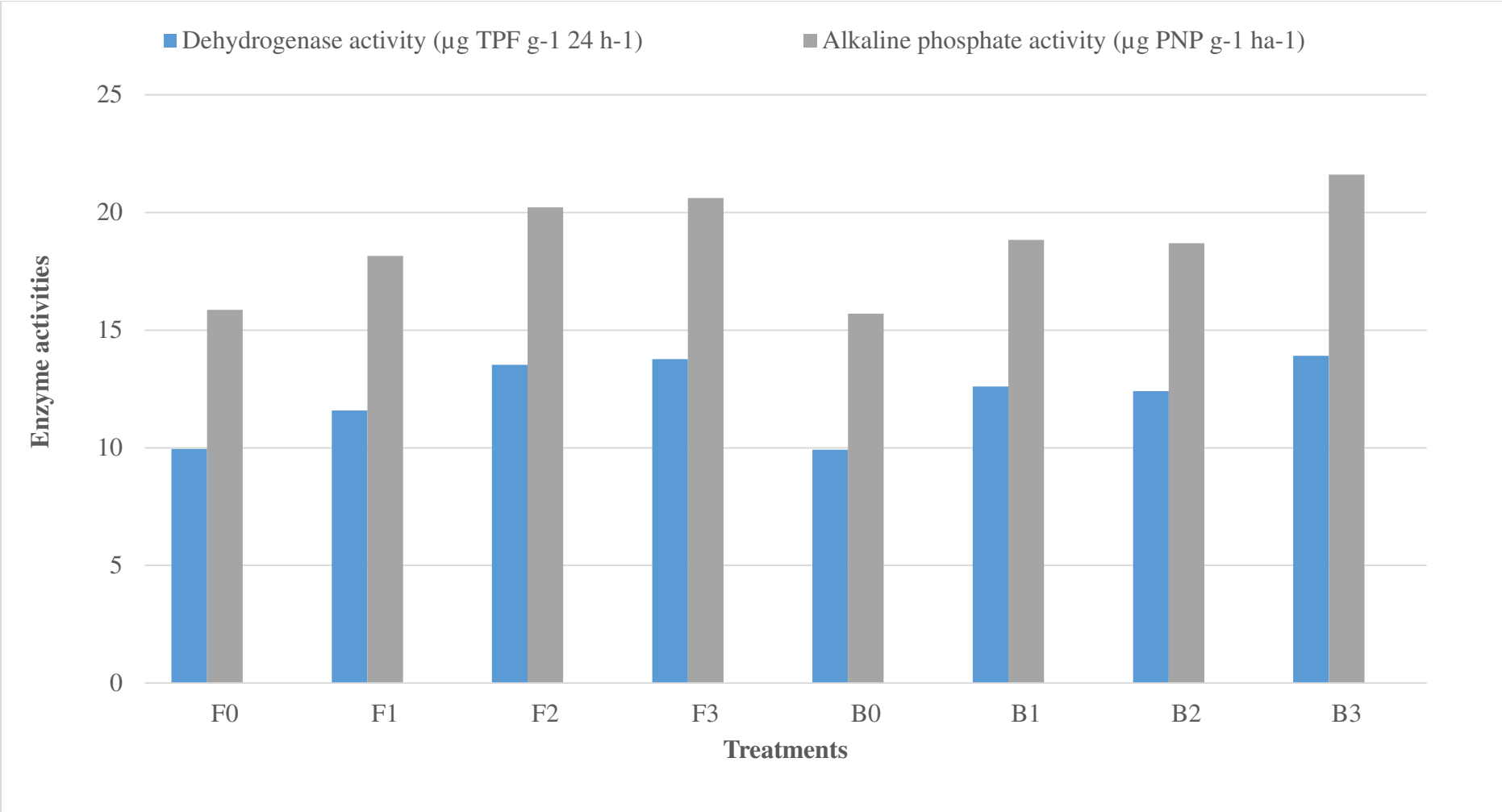
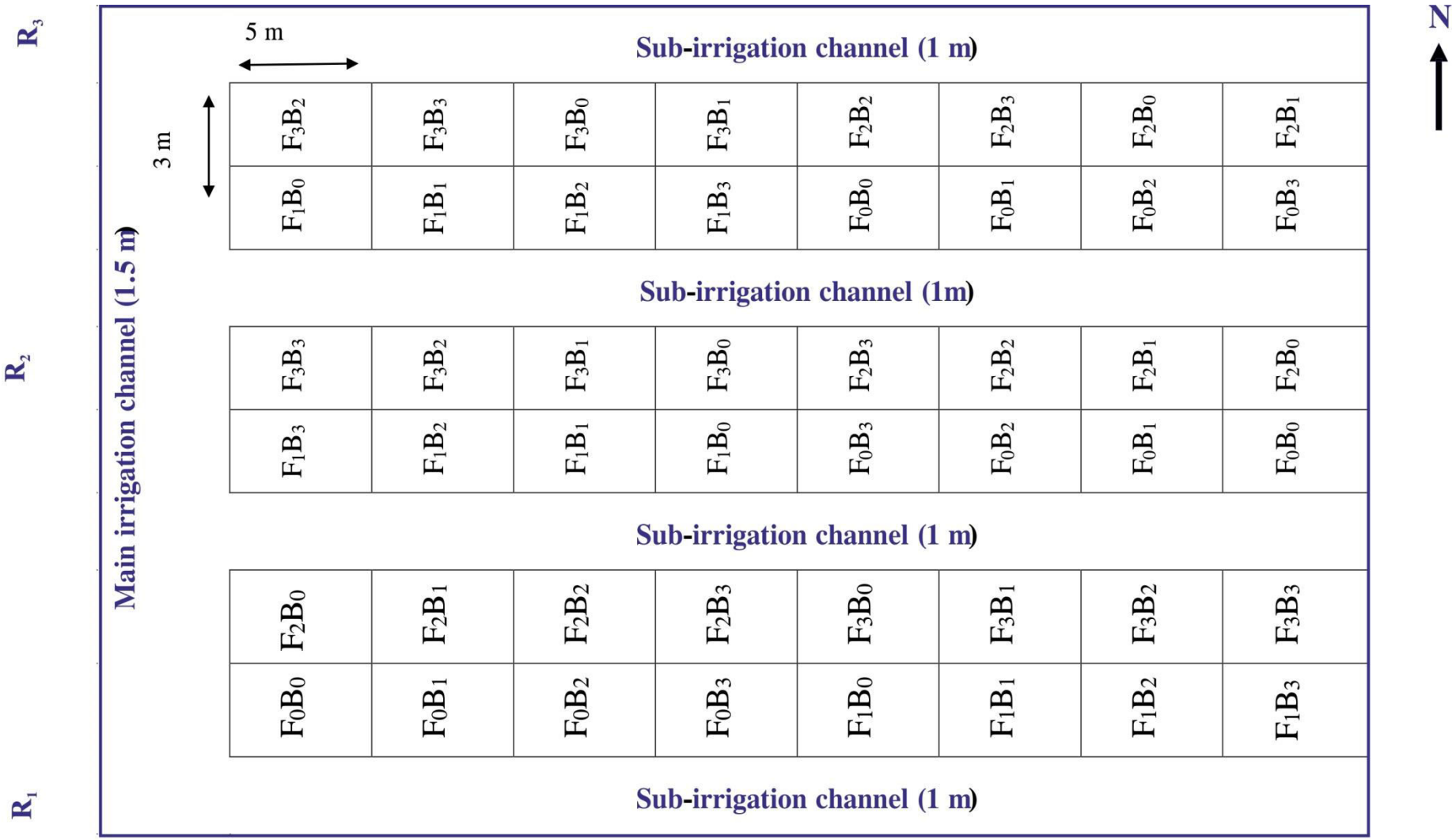


Fig. 4.18 Effect of fertility levels and liquid biofertilizers on enzyme activities in soil after crop harvest



Experimental Details: Factorial Randomized block Design; Treatments-16, Replication-3; Plot size-3.0 m×5.0 m

Fig. 3.2 Plan of layout

Table 3.2: Mean weekly weather parameters for crop season (*Rabi*, 2019-20)

Standard meteorological week	Week no.	Temperature (°C)		Relative humidity (%)		Wind velocity (km h^{-1})	Sunshine hours day^{-1}	Rainfall (mm)	Evaporation (mm day^{-1})
		Max.	Min.	Max.	Min.				
18 Dec-23 Dec	51	23.5	6.6	82.4	40.1	2.6	7.2	0.0	2.1
24 Dec-31Dec	52	21.5	4.7	82.6	40.1	2.4	5.8	0.0	2.2
1 Jan.-7 Jan	1	21.2	6.8	86.7	49.3	2.7	5.1	0.0	2.2
8 Jan.-14 Jan	2	22.1	5.2	81.7	40.4	3.2	7.1	0.0	4.5
15 Jan-21 Jan	3	21.0	6.4	86.4	42.0	2.3	5.6	0.0	2.4
22 Jan-28 Jan	4	24.7	7.9	82.7	31.3	2.7	8.6	0.0	3.3
29 Jan-4 Feb	5	22.3	4.5	85.0	36.3	3.0	8.6	0.0	2.7
5 Feb-11 Feb	6	23.0	4.4	80.3	34.4	2.6	8.6	0.0	3.1
12 Feb -18 Feb	7	28.5	7.7	77.4	21.9	2.3	8.6	0.0	3.8
19 Feb-25 Feb	8	28.1	9.0	76.3	28.9	2.9	7.9	0.0	4.5
26 Feb-4 Mar	9	30.2	10.9	73.4	26.6	2.4	7.6	0.0	4.5
5 Mar-11 Mar	10	26.6	10.2	71.9	33.3	5.1	9.0	3.0	7.1
12 Mar-18 Mar	11	26.9	8.6	62.7	22.6	4.3	8.1	0.0	5.3
19 Mar-25 Mar	12	33.0	14.5	54.7	29.0	2.3	7.8	2.6	4.3
26 Mar-1 Apr	13	30.8	13.5	76.7	22.7	3.2	7.7	29.0	6.1
2 Apr-8 Apr	14	34.6	14.6	53.6	19.9	3.4	9.9	0.0	6.8
9 Apr-15 Apr	15	37.3	17.5	57.6	16.7	3.0	8.6	0.0	8.2
16 Apr-22 Apr	16	36.8	19.8	50.1	20.3	5.5	9.0	0.0	9.9
23 Apr-29 Apr	17	37.3	20.8	51.0	21.6	5.3	9.1	8.0	9.2

Source: Agro Meteorological Observatory, Rajasthan College of Agriculture, MPUAT, Udaipur

Table 4.1: Effect of fertility levels and liquid biofertilizers on growth and yield attributes

Treatments	Plant height (cm)			No. of total tillers (per metre row length)	No. of effective tillers (per metre 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)	41.80	71.69	94.15	87.23	71.85	41.34
100 % RDF (F_2)	44.10	77.49	100.91	95.25	76.47	43.90
125 % RDF (F_3)	44.90	79.30	102.30	96.10	77.23	44.20
SEm±	0.68	1.85	2.27	2.51	1.58	0.85
C.D. (P = 0.05)	1.97	5.36	6.55	7.25	4.58	2.47
Liquid biofertilizers						
No inoculation (B_0)	34.89	63.22	86.72	79.79	65.42	38.33
Azotobacter (B_1)	41.05	71.69	93.20	85.26	69.50	40.12
PSB (B_2)	39.30	70.51	91.11	84.73	68.00	39.74
Azo + PSB (B_3)	42.86	76.46	99.53	93.51	75.10	43.36
SEm±	0.68	1.85	2.27	2.51	1.58	0.85
C.D. (P = 0.05)	1.97	5.36	6.55	7.25	4.58	2.47

Table 4.2: Effect of fertility levels and liquid biofertilizers on grain yield, stover yield, biological yield and harvest index of wheat

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Fertility levels (RDF)				
Control (F_0)	3038.96	5043.62	8082.58	37.19
75 % RDF (F_1)	4596.62	6305.24	10901.86	41.99
100 % RDF (F_2)	4917.51	6649.19	11566.70	42.43
125 % RDF (F_3)	5073.97	6828.19	11902.16	42.45
SEm±	96.81	137.70	186.63	1.55
C.D. (P = 0.05)	279.63	397.72	539.03	NS
Liquid biofertilizers				
No inoculation (B_0)	3072.09	5019.32	8091.41	39.64
Azotobacter (B_1)	4444.21	6136.38	10580.59	41.51
PSB (B_2)	4350.50	6036.55	10387.05	40.86
Azo + PSB (B_3)	5060.26	6801.00	11861.26	42.06
SEm±	96.81	137.70	186.63	1.55
C.D. (P = 0.05)	279.63	397.72	539.03	NS

Table 4.3: Interaction effect of fertility levels and liquid biofertilizers on grain yield of wheat

Treatments	Grain yield (kg ha^{-1})			
	F_0	F_1	F_2	F_3
B_0	1547.43	3308.61	3356.71	4075.61
B_1	3324.04	4420.30	5554.67	5177.82
B_2	3247.30	4473.18	5041.33	5040.19
B_3	4037.07	4584.40	6017.32	6002.24
SEm±	193.63			
C.D. (P = 0.05)	559.26			

Table 4.4: Interaction effect of fertility levels and liquid biofertilizers on straw yield of wheat

Treatments	Straw yield (kg ha^{-1})			
	F_0	F_1	F_2	F_3
B_0	3560.93	4157.67	6465.27	5893.41
B_1	5244.51	6222.30	6643.05	7111.20
B_2	5368.96	6029.71	6614.11	7057.87
B_3	6000.08	7211.29	7274.35	7250.28
SEm±	275.41			
C.D. (P = 0.05)	795.45			

Table 4.5: Effect of fertility levels and liquid biofertilizers on nitrogen, phosphorus, potassium and sulphur content of wheat

Treatments	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		Sulphur content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Fertility levels (RDF)								
Control (F_0)	1.416	0.460	0.277	0.187	0.483	1.345	0.173	0.145
75 % RDF (F_1)	1.490	0.512	0.311	0.203	0.521	1.435	0.193	0.153
100 % RDF (F_2)	1.516	0.531	0.322	0.209	0.535	1.465	0.199	0.157
125 % RDF (F_3)	1.519	0.533	0.326	0.211	0.545	1.468	0.202	0.158
SEm±	0.008	0.006	0.002	0.002	0.005	0.010	0.002	0.001
C.D. (P = 0.05)	0.023	0.018	0.005	0.005	0.014	0.029	0.006	0.004
Liquid biofertilizers								
No inoculation (B_0)	1.414	0.457	0.276	0.186	0.484	1.330	0.170	0.144
Azotobacter (B_1)	1.481	0.503	0.301	0.198	0.511	1.411	0.187	0.152
PSB (B_2)	1.470	0.488	0.297	0.195	0.499	1.387	0.183	0.150
Azo + PSB (B_3)	1.518	0.532	0.325	0.208	0.538	1.466	0.203	0.161
SEm±	0.008	0.006	0.002	0.002	0.005	0.010	0.002	0.001
C.D. (P = 0.05)	0.023	0.018	0.005	0.005	0.014	0.029	0.006	0.004

Table 4.6: Effect of fertility levels and liquid biofertilizers on zinc, iron, manganese and copper content of wheat

Treatments	Zinc content (ppm)		Iron content (ppm)		Manganese content (ppm)		Copper content (ppm)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Fertility levels (RDF)								
Control (F_0)	26.00	13.23	72.90	144.63	13.25	21.26	7.57	3.34
75 % RDF (F_1)	26.45	13.43	74.86	146.88	13.59	21.74	7.72	3.50
100 % RDF (F_2)	26.92	13.64	75.91	148.66	13.95	22.32	7.86	3.64
125 % RDF (F_3)	26.95	13.65	76.09	148.89	13.97	22.51	7.87	3.66
SEm±	0.15	0.06	0.52	0.614	0.109	0.16	0.04	0.03
C.D. (P = 0.05)	0.44	0.19	1.50	1.774	0.313	0.46	0.13	0.10
Liquid biofertilizers								
No inoculation (B_0)	26.14	13.25	72.95	144.85	13.50	21.44	7.69	3.38
Azotobacter (B_1)	26.39	13.30	75.26	147.96	13.65	21.69	7.60	3.50
PSB (B_2)	26.36	13.29	73.99	146.88	13.52	21.45	7.60	3.58
Azo + PSB (B_3)	26.47	13.43	75.57	148.84	13.89	21.70	7.78	3.50
SEm±	0.15	0.10	0.62	0.61	0.11	0.22	0.07	0.03
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.7: Effect of fertility levels and liquid biofertilizers on nitrogen, phosphorus, potassium and sulphur uptake by wheat

Treatments	Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})		Sulphur uptake (kg ha^{-1})	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
Fertility levels (RDF)								
Control (F_0)	43.03	23.20	8.41	9.43	14.67	67.83	5.25	7.31
75 % RDF (F_1)	68.48	32.28	14.29	12.79	23.94	90.48	8.87	9.64
100 % RDF (F_2)	74.54	35.30	15.83	13.89	26.30	97.41	9.78	10.43
125 % RDF (F_3)	77.07	36.39	16.54	14.40	27.65	100.23	10.24	10.78
SEm±	1.47	0.66	0.33	0.26	0.52	1.88	0.19	0.23
C.D. (P = 0.05)	4.27	1.92	0.95	0.77	1.52	5.43	0.56	0.66
Liquid biofertilizers								
No inoculation (B_0)	43.43	22.93	8.47	9.33	14.86	66.75	5.22	7.22
Azotobacter (B_1)	65.81	30.86	13.37	12.15	22.70	86.58	8.31	9.32
PSB (B_2)	63.95	29.45	12.92	11.77	21.70	83.72	7.96	9.05
Azo + PSB (B_3)	76.81	36.18	16.44	14.14	27.22	99.70	10.27	10.94
SEm±	1.47	0.66	0.33	0.26	0.52	1.88	0.19	0.23
C.D. (P = 0.05)	4.27	1.92	0.95	0.77	1.52	5.43	0.56	0.66

Table 4.8: Interaction effect of fertility levels and liquid biofertilizers on nitrogen uptake by grain

Treatments	Nitrogen uptake (kg ha^{-1})			
	F_0	F_1	F_2	F_3
B_0	21.27	46.30	49.13	57.75
B_1	46.82	67.64	84.43	79.00
B_2	46.73	65.36	75.72	76.63
B_3	58.20	68.35	92.43	96.36
SEm±	2.96			
C.D. (P = 0.05)	8.55			

Table 4.9: Interaction effect of fertility levels and liquid biofertilizers on nitrogen uptake by straw

Treatments	Nitrogen uptake (kg ha^{-1})			
	F_0	F_1	F_2	F_3
B_0	14.80	18.63	31.78	27.93
B_1	25.52	30.71	35.67	38.41
B_2	24.48	29.78	35.46	37.77
B_3	28.80	37.23	39.72	42.33
SEm±	1.34			
C.D. (P = 0.05)	3.87			

Table 4.10: Interaction effect of fertility levels and liquid biofertilizers on phosphorus uptake by grain

Treatments	Phosphorus uptake (kg ha^{-1})			
	F_0	F_1	F_2	F_3
B_0	3.87	8.97	9.90	11.70
B_1	9.43	13.23	18.37	17.36
B_2	9.11	13.31	16.56	16.69
B_3	11.94	14.37	20.45	20.98
SEm±	0.66			
C.D. (P = 0.05)	1.90			

Table 4.11: Interaction effect of fertility levels and liquid biofertilizers on phosphorus uptake by straw

Treatments	Phosphorus uptake (kg ha^{-1})			
	F_0	F_1	F_2	F_3
B_0	6.10	7.65	12.66	11.43
B_1	10.32	12.20	13.95	15.38
B_2	9.91	11.71	13.52	15.06
B_3	11.69	14.93	15.94	15.28
SEm±	0.53			
C.D. (P = 0.05)	1.54			

Table 4.12: Interaction effect of fertility levels and liquid biofertilizers on potassium uptake by grain

Treatments	Potassium uptake (kg ha^{-1})			
	F_0	F_1	F_2	F_3
B_0	7.24	15.95	17.43	19.02
B_1	16.16	22.30	30.10	29.02
B_2	15.75	22.00	27.07	28.34
B_3	19.97	23.70	33.15	35.47
SEm±	1.05			
C.D. (P = 0.05)	3.05			

Table 4.13: Interaction effect of fertility levels and liquid biofertilizers on potassium uptake by straw

Treatments	Potassium uptake (kg ha^{-1})			
	F_0	F_1	F_2	F_3
B_0	45.32	55.01	89.89	78.84
B_1	73.36	87.88	98.33	105.25
B_2	70.45	83.94	96.81	103.85
B_3	83.83	102.51	108.70	112.38
SEm±	3.83			
C.D. (P = 0.05)	11.06			

Table 4.14: Effect of fertility levels and liquid biofertilizers on zinc, iron, manganese and copper uptake by wheat

Treatments	Zinc uptake (g ha^{-1})		Iron uptake (g ha^{-1})		Manganese uptake (g ha^{-1})		Copper uptake (g ha^{-1})	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
Fertility levels (RDF)								
Control (F_0)	79.01	66.72	221.55	729.47	40.28	107.25	23.02	16.85
75 % RDF (F_1)	121.58	84.67	344.13	926.14	62.46	137.11	35.48	22.11
100 % RDF (F_2)	132.37	90.69	373.31	988.46	68.61	148.40	38.65	24.26
125 % RDF (F_3)	136.74	93.20	386.09	1016.69	70.89	153.75	39.93	25.03
SEm±	2.36	1.91	7.27	19.35	1.47	3.24	0.72	0.48
C.D. (P = 0.05)	6.83	5.58	21.007	55.91	4.26	9.38	2.10	1.40
Liquid biofertilizers								
No inoculation (B_0)	80.30	66.50	224.11	727.06	41.49	107.65	23.63	16.98
Azotobacter (B_1)	117.28	81.61	334.48	907.95	60.67	133.12	33.79	21.50
PSB (B_2)	114.67	80.22	321.89	886.69	58.83	129.49	33.07	21.62
Azo + PSB (B_3)	133.94	91.33	382.42	1012.28	70.28	147.60	39.41	23.81
SEm±	2.36	1.91	7.273	19.35	1.47	3.24	0.72	0.48
C.D. (P = 0.05)	6.83	5.51	21.007	55.91	4.26	9.38	2.10	1.40

Table 4.15: Effect of fertility levels and liquid biofertilizers on BD, PD, Porosity, pH, EC and OC in soil after crop harvest

Treatments	BD (Mg m^{-3})	PD(Mg m^{-3})	Porosity (%)	pH	EC (dS m^{-1})	OC (%)
Fertility levels (RDF)						
Control (F_0)	1.38	2.56	45.86	8.20	0.62	0.62
75 % RDF (F_1)	1.39	2.51	44.45	8.19	0.60	0.62
100 % RDF (F_2)	1.40	2.52	44.45	8.15	0.58	0.63
125 % RDF (F_3)	1.41	2.54	44.45	8.07	0.58	0.63
SEm±	0.03	0.07	0.59	0.15	0.02	0.01
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Liquid biofertilizers						
No inoculation (B_0)	1.38	2.58	45.86	8.18	0.59	0.62
Azotobacter (B_1)	1.41	2.53	44.45	8.17	0.59	0.62
PSB (B_2)	1.38	2.48	44.45	8.15	0.59	0.62
Azo + PSB (B_3)	1.41	2.54	44.45	8.10	0.59	0.63
SEm±	0.03	0.07	0.59	0.15	0.02	0.01
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS

Table 4.16: Effect of fertility levels and liquid biofertilizers on nutrient availability in soilafter crop harvest

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Sulphur (mg ha^{-1})	Zinc (mg ha^{-1})	Iron (mg ha^{-1})	Manganese (mg ha^{-1})	Copper (mg ha^{-1})
Fertility levels (RDF)								
Control (F_0)	270.28	21.01	386.82	9.11	0.67	4.35	8.91	2.05
75 % RDF (F_1)	294.58	24.32	431.36	9.84	0.70	5.04	9.35	2.08
100 % RDF (F_2)	305.1	25.28	445.8	10.16	0.73	5.57	9.76	2.10
125 % RDF (F_3)	308.31	25.53	447.57	10.18	0.73	5.58	9.82	2.11
SEm±	3.29	0.29	4.68	0.10	0.01	0.02	0.13	0.01
C.D. (P = 0.05)	9.51	0.84	13.52	0.30	0.02	0.06	0.38	0.02
Liquid biofertilizers								
No inoculation (B_0)	276.36	21.09	378.14	9.49	0.68	5.02	9.16	2.06
Azotobacter (B_1)	293.2	22.72	414.5	9.72	0.69	4.67	9.32	2.07
PSB (B_2)	287.54	23.44	404.73	9.79	0.69	4.65	9.21	2.08
Azo + PSB (B_3)	303.73	25.20	447.08	9.92	0.69	5.05	9.36	2.08
SEm±	3.29	0.29	4.68	0.10	0.01	0.02	0.13	0.01
C.D. (P = 0.05)	9.51	0.84	13.52	0.30	NS	NS	NS	NS

Table 4.17: Effect of fertility levels and liquid biofertilizers on biological properties of soil after crop harvest

Treatments	Microbial population			Soil microbial biomass		Enzyme activities	
	Bacterial (10^7cfu g^{-1} of soil)	Fungal (10^5cfu g^{-1} of soil)	Actinomycetes (10^6cfu g^{-1} of soil)	Carbon (mg kg^{-1})	Nitrogen (mg kg^{-1})	Dehydrogenase activity (µg TPF g^{-1} 24 h^{-1})	Alkaline phosphate activity (µg PNP g^{-1} ha^{-1})
Fertility levels (RDF)							
Control (F_0)	63.64	23.39	34.88	165.82	25.14	9.95	15.86
75 % RDF (F_1)	69.09	24.44	38.29	176.47	26.33	11.58	18.15
100 % RDF (F_2)	73.62	25.42	40.66	185.70	27.88	13.53	20.21
125 % RDF (F_3)	75.29	25.81	40.86	188.98	28.65	13.77	20.61
SEm±	1.08	0.29	0.37	1.61	0.31	0.23	0.22
C.D. (P = 0.05)	3.12	0.84	1.08	4.65	0.90	0.68	0.64
Liquid biofertilizers							
No inoculation (B_0)	63.41	22.44	34.83	169.92	24.90	9.92	15.70
Azotobacter (B_1)	71.67	25.08	39.28	179.58	27.37	12.60	18.83
PSB (B_2)	70.68	24.68	38.96	178.00	26.54	12.41	18.69
Azo + PSB (B_3)	75.88	27.33	41.61	189.48	29.18	13.91	21.61
SEm±	1.08	0.29	0.37	1.61	0.31	0.23	0.22
C.D. (P = 0.05)	3.12	0.84	1.08	4.65	0.90	0.68	0.64

Table 4.18: Interaction effect of fertility levels and liquid biofertilizers on bacterial population in soil after crop harvest

Treatments	Bacterial population (10^7cfu g^{-1} of soil)			
	F_0	F_1	F_2	F_3
B_0	55.63	60.68	66.28	71.05
B_1	65.36	69.58	73.60	78.15
B_2	64.45	70.48	73.30	74.51
B_3	69.12	75.63	81.31	77.47
SEm±	2.16			
C.D. (P = 0.05)	6.25			

Table 4.19: Effect of fertility levels and liquid biofertilizers on net return (` ha^{-1}) and B C ratio

Treatments	Net return (` ha^{-1})	B C ratio
Fertility levels (RDF)		
Control (F_0)	59171.76	2.57
75 % RDF (F_1)	81346.21	3.01
100 % RDF (F_2)	99341.18	3.48
125 % RDF (F_3)	99437.04	3.28
SEm±	2101.82	0.07
C.D. (P = 0.05)	6070.50	0.21
Liquid biofertilizers		
No inoculation (B_0)	60570.90	2.18
Azotobacter (B_1)	90152.19	3.29
PSB (B_2)	85897.56	3.13
Azo + PSB (B_3)	102675.54	3.74
SEm±	2101.82	0.07
C.D. (P = 0.05)	6070.50	0.21

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	Hindi	:	**eDdk&xsgw¡ Qlyi)fresamoZjdksa ,oa [kknksa ds nh?kZdkfydvuqiz;ksxdkfeV~Vh dh xq.koÙkkrFkkdkcZulao/kZuijizHkko**
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APPENDIX-I

Analysis variance for effect of fertility levels and liquid biofertilizers on plant height, no. of tillers and test weight

Source of variance	d. f.	Mean sum of square					
		Plant height			No. of tillers		
		At 30 DAS	At 60 DAS	At harvest	Total tillers	Effective tillers	Test weight
Replication	2	2.13165	0.87934	15.07836	6.33672	28.98941	1.11236
Fertility levels (F)	3	184.474778**	462.599978**	599.632166**	592.730268**	490.399433**	106.769762**
Biofertilizers (B)	3	151.884564**	359.905392**	333.683032**	382.693746**	194.888366**	51.986752**
F×B	9	11.276723	22.425425	5.176784	22.674846	1.623044	2.317482
Error B	30	5.614486	41.324477	61.843617	75.719637	30.250193	8.837915

* Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-II

Analysis variance for effect of fertility levels and liquid biofertilizers on yield and harvest index

Source of variance	d. f.	Mean sum of square			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	3827.06587	81622.15788	52230.42231	15.07024
F	3	10844029.159571**	8433015.264317**	38314828.719620**	78.657020
B	3	6406610.856745**	7735839.810018**	28196491.448720**	13.035398
F×B	9	301626.673976*	655729.462606*	397078.855053	35.502484
Error B	30	113018.371719	232676.952013	418828.322144	29.053954

* Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-III

Analysis variance for effect of fertility levels and liquid biofertilizers on nutrient content (N, P, K and S) in grain and stover

Source of variance	d. f.	Mean sum of square							
		Nitrogen		Phosphorus		Potassium		Sulphur	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Replication	2	0.00014	0.00012	0.00000	0.00006	0.00073	0.00286	0.00003	0.00003
F	3	0.023454**	0.014471**	0.006270**	0.001278**	0.010236**	0.038034**	0.002339**	0.000464**
B	3	0.023442**	0.012007**	0.005155**	0.001057**	0.006281**	0.040753**	0.002228**	0.000533**
F×B	9	0.003032**	0.000336	0.000060	0.000044	0.001411**	0.001405	0.000008	0.000019
Error B	30	0.000754	0.000483	0.000038	0.000038	0.000277	0.001227	0.000060	0.000026

* Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-IV

Analysis variance for effect of fertility levels and liquid biofertilizers on nutrient content (Zn, Fe, Mn and Cu) in grain and straw

Source of variance	d. f.	Mean sum of square							
		Zinc		Iron		Manganese		Copper	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Replication	2	0.47297	0.05457	2.41939	0.71250	0.27994	0.03436	0.12664	0.00469
F	3	0.728519**	0.040135**	5.634356**	9.932591**	0.007339**	0.022176**	0.148858**	0.008311**
B	3	0.239112	0.070471	0.991845	2.697101	0.375832	0.009597	0.095119	0.037178
F×B	9	0.097454	0.132048	2.554037	10.390101	0.221443	0.199601	0.210619	0.038820
Error B	30	0.275424	0.127572	4.747836	4.525735	0.141319	0.604808	0.069888	0.015853

* Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-V

Analysis variance for effect of fertility levels and liquid biofertilizers on nutrient uptake (N, P, K and S) in grain and straw

Source of variance	d. f.	Mean sum of square							
		Nitrogen		Phosphorus		Potassium		Sulphur	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Replication	2	0.29009	4.63440	0.04597	0.11834	0.96332	35.50509	0.07269	0.30567
F	3	2975.606268**	459.440633**	172.890062**	60.782835**	442.839389**	2711.135692**	66.076801**	31.497935**
B	3	1917.527388**	395.827565**	112.296204**	52.717381**	273.272420**	2525.219996**	44.442763**	29.644727**
F×B	9	64.632671*	13.019739*	3.087403*	2.587319*	9.120543*	100.109141*	1.315125*	1.493565*
Error B	30	26.314485	5.395576	1.310406	0.855704	3.353527	44.055561	0.458276	0.655387

* Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-VI

Analysis variance for effect of fertility levels and liquid biofertilizers on nutrient uptake (Zn, Fe, Mn and Cu) in grain and straw

Source of variance	d. f.	Mean sum of square							
		Zinc		Iron		Manganese		Copper	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Replication	2	10.06965	30.12188	47.30178	1736.32660	8.64013	52.84903	4.93081	1.25096
F	3	8024.984541**	1563.579998**	64582.311094**	190458.190747**	2072.959750**	4107.292581**	695.687806**	114.289463**
B	3	4669.074810**	1474.929672**	37108.690978**	167228.543090**	1372.570677**	3751.615298**	385.790132**	119.020281**
F×B	9	197.892091*	98.733001	1610.746438*	16882.854981**	61.474247*	249.585407	22.310104**	4.725331
Error B	30	67.388961	46.191982	673.073574	4630.081953	25.831538	138.751282	6.873217	2.843169

Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-VII

Analysis variance for effect of fertility levels and liquid biofertilizers on physio-chemical properties of soil after crop harvest

Source of variance	d. f.	Mean sum of square					
		Bulk density	Particle density	Porosity	pH	EC	Organic carbon
Replication	2	0.00184	0.02680	4.20955	0.28083	0.00213	0.00050
F	3	0.002422	0.008054	6.008242	0.044063	0.003540	0.000530
B	3	0.003466	0.018594	6.008242	0.016592	0.000011	0.000250
F×B	9	0.026388	0.083621	6.008242	0.001725	0.000202	0.000869
Error B	30	0.010697	0.057343	4.209554	0.292589	0.002725	0.000721

* Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-VIII

Analysis variance for effect of fertility levels and liquid biofertilizers on available nutrients in soil after crop harvest

Source of variance	d. f.	Mean sum of square							
		Available nutrients							
		Nitrogen	Phosphorus	Potassium	Sulphur	Zinc	Iron	Manganese	Copper
Replication	2	45.43201	0.28496	36.62281	0.31199	0.01237	0.00375	0.00179	0.00180
F	3	3365.641825**	52.575103**	10241.147166**	2.894995**	0.004534**	0.011145**	0.190748**	0.000156
B	3	1556.617447**	37.543994**	10525.587311**	0.554306*	0.006140	0.001659	0.136665	0.000925
F×B	9	80.410118	1.483833	702.872365*	0.020475	0.015559	0.072343	0.492802**	0.028037**
Error B	30	130.100120	1.017175	263.079683	0.137190	0.007321	0.006585	0.274030	0.006638

* Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-IX

Analysis variance for effect of fertility levels and liquid biofertilizers on biological properties of soil after crop harvest

Source of variance	d. f.	Mean sum of square						
		Microbial population			Soil microbial biomass		Enzyme activities	
		Bacterial	Fungal	Actinomycetes	Carbon	Nitrogen	Dehydrogenase	Alkaline phosphate activity
Replication	2	26.45858	1.52954	1.14263	23.07287	1.16712	1.03982	0.40676
F	3	433.214671**	41.545395**	126.479216**	1500.975257**	36.016896**	38.733980**	78.433511**
B	3	274.109498**	28.980042**	71.471302**	532.091536**	23.146326**	28.277099**	42.670815**
F×B	9	11.858030	0.478176	0.846321	53.381243	1.299739	0.181295	0.273572
Error B	30	14.073858	1.016985	1.697435	32.245581	1.174409	0.574504	0.590012

* Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-X

Analysis variance for effect of fertility levels and liquid biofertilizers on economics

Source of variance	d. f.	Mean sum of square	
		Net return	B C ratio
Replication	2	240415	0.00001
F	3	4377687806**	1.881845**
B	3	3745729331**	5.126439**
F×B	9	72682074	0.170509*
Error B	30	53011982	0.067318

* Significant at 5 per cent significant levels; * *Significant at 1 per cent significant levels

APPENDIX-XI

Common cost of cultivation of crop

Common cost of cultivars	Unit cost (`)	Cost ha^{-1} (`)
Land preparation (8 hrs.)	500 hr^{-1}	4000
Layout and bunding (10 man days)	250 man day^{-1}	2500
Seed (125 kg ha^{-1})	45 kg^{-1}	5625
Seed treatment (2 mandays)	250 $manday^{-1}$	500
Sowing & fertilizer application (8 man days)	250 $manday^{-1}$	2000
2,4-D (0.5 a.i.ha^{-1}) + isoproturon	1760 kg^{-1}	1760
Herbicide spray (2 mandays)	250 man day^{-1}	500
Irrigation (1 palewa + 5 including labour)	520 $irrigation^{-1}$	3120
Harvesting (15 $manday^{-1}$)	250 $manday^{-1}$	3750
Threshing and winnowing (6 hrs) + manpower (6)	500 hr^{-1}+ 189 $manday^{-1}$	4134
Miscellanous		411
Total		28300
Cost of inputs		
Azotobacter	200 lit^{-1}	
PSB	200 lit^{-1}	
DAP	24 kg^{-1}	
Urea	6 kg^{-1}	
MOP	16 kg^{-1}	
Price of produce		
Grain	19.25/-	
Stover	3.00/-	

APPENDIX-XII

Comparative economics for various treatment combinations for wheat

Treatment	Treatment combinations	Treatment cost	Common cost	Total cost	Grain yield	Stover yield	Gross return	Net return	B C ratio
T_1	F_0B_0	0	28300	28300	1547.43	3560.93	51611.70	28716.70	1.25
T_2	F_0B_1	200	28300	28500	3324.04	5244.51	87549.54	64564.54	2.81
T_3	F_0B_2	200	28300	28500	3247.30	5368.96	85487.88	62412.88	2.70
T_4	F_0B_3	400	28300	28700	4037.07	6000.08	104157.93	80992.93	3.50
T_5	F_1B_0	4132	28300	32432	3308.61	4157.67	87968.19	61073.19	2.27
T_6	F_1B_1	4332	28300	32632	4420.30	6222.30	112517.17	85532.17	3.17
T_7	F_1B_2	4332	28300	32632	4473.18	6029.71	112587.80	85512.80	3.16
T_8	F_1B_3	4532	28300	32832	4584.40	7211.29	120431.68	93266.68	3.43
T_9	F_2B_0	5470	28300	33770	3356.71	6465.27	100074.08	71679.08	2.52
T_{10}	F_2B_1	5670	28300	33970	5554.67	6643.05	138010.84	109525.84	3.85
T_{11}	F_2B_2	5670	28300	33970	5041.33	6614.11	126217.04	97642.04	3.42
T_{12}	F_2B_3	5870	28300	34170	6017.32	7274.35	147182.77	118517.77	4.13
T_{13}	F_3B_0	6852	28300	35152	4075.60	5893.41	110959.65	80814.65	2.68
T_{14}	F_3B_1	7052	28300	35352	5177.82	7111.20	131221.23	100986.23	3.34
T_{15}	F_3B_2	7052	28300	35352	5040.19	7057.87	128347.52	98022.52	3.23
T_{16}	F_3B_3	7252	28300	35552	6002.24	7250.28	148339.78	117924.78	3.88

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