Effect of Fertility Levels, Organic Sources and Bio-Inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts

हेप्लुस्टेप्स में गेहूँ (*ट्रिटिकम एस्टीवम* एल.) में उर्वरता स्तरों, जैविक खाद व जीवाणु खाद का मृदा गुणों, पोषक तत्व अवशोषण तथा उत्पादकता पर प्रभाव

SUBHITA KUMARI

Thesis

Doctor of Philosophy in Agriculture

(Soil Science)

2021

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY UDAIPUR (RAJASTHAN) - 313 001

Effect of Fertility Levels, Organic Sources and Bio-Inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts

हेप्लुस्टेप्स में गेहूँ (*ट्रिटिकम एस्टीवम* एल.) में उर्वरता स्तरों, जैविक खाद व जीवाणु खाद का मृदा गुणों, पोषक तत्व अवशोषण तथा उत्पादकता पर प्रभाव

Thesis
Submitted to the
Maharana Pratap University of Agriculture and Technology, Udaipur
in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Agriculture

(Soil Science)

By

SUBHITA KUMARI

2021

CERTIFICATE - I

CERTIFICATE OF ORIGINALITY

The research work embodied in this thesis titled **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** submitted for the award of degree of **Doctor of Philosophy** in Agriculture in the subject of **Soil Science and Agricultural Chemistry,** to Maharana Pratap University of Agriculture and Technology, Udaipur (Raj.) is original and bona fide record of research work carried out by me under the supervision of **Dr. Mahendra Sharma,** Professor, Department of Soil Science and Agricultural Chemistry, Rajasthan College of Agriculture. 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.

The manuscript has been subjected to plagiarism check by software Urkund.

It is certified that as per the check, the similarity index of the content is 8% and is within permissible limit as per the MPUAT guideline on checking Plagiarism.

Date: 19/01/2021 **(Subhita Kumari)**

RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR

CERTIFICATE - II

Dated: 19/01/2021

This is to certify that the thesis entitled **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** submitted for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Soil Science and Agricultural Chemistry**, embodies bonafide research work carried out by **Mrs. Subhita Kumari** 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 / /2021.

The manuscript has been subjected to plagiarism check by software Urkund.

It is certified that as per the check, the similarity index of the content is 8% and is within permissible limit as per the MPUAT guideline on checking Plagiarism.

(Dr. R.H. Meena)
Head
Department of Soil Science
and Agricultural Chemistry

(Dr. Mahendra Sharma)
Major Advisor
Department of Soil Science
and Agricultural Chemistry

(Dr. Dilip Singh)
Dean
Rajasthan College of Agriculture
Maharana Pratap University of Agriculture and Technology,
Udaipur (Raj.) 313 001

RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR

CERTIFICATE - III

Dated: / /2021

This is to certify that the thesis entitled **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of wheat (*Triticum aestivum* L.) in Haplustepts"** submitted by **Mrs. Subhita Kumari** to the Maharana Pratap University of Agriculture and Technology, Udaipur in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Soil Science and Agricultural Chemistry** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory, we therefore, recommend that the thesis be approved.

(Dr. Mahendra Sharma) Major Advisor	**(Dr. V. Nepalia)** Advisor
(Dr. H. S. Purohit) Advisor	**(Dr. B. Upadhyay)** Advisor
(Dr. Natwar Singh) DRI, Nominee	**(Dr. S. K. Trivedi)** External Examiner
(Dr. R.H. Meena) Head Department of Soil Science and Agricultural Chemistry	**(Dr. Dilip Singh)** Dean R.C.A. Udaipur

Approved

(Dr. S. R. Bhakar)
Director Resident Instructions
Maharana Pratap University of Agriculture and Technology, Udaipur
Rajasthan College of Agriculture

RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR

CERTIFICATE - IV

Dated: /   /2021

This is to certify that **Mrs. Subhita Kumari** of the **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, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** which were suggested by the external examiner and the advisory committee in the oral examination held on -------------- The final copies of the thesis duly bound and corrected were submitted on ---------------- are enclosed herewith for approvals.

(Dr. R.H. Meena)
Head
Department of Soil Science
and Agricultural Chemistry

(Dr. Mahendra Sharma)
Major Advisor
Department of Soil Science
and Agricultural Chemistry

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ACRONYMS

%	=	Per cent	m ha	=	Million hectare
°C	=	Degree Celsius	m^2	=	Meter square
°E	=	Degree East	m^3	=	Meter cubic
°N	=	Degree North	Max.	=	Maximum
/	=	Per	mg		Milligrams
@	=	At the rate of	Mg	=	Megagrams
ANOVA	=	Analysis of variance	mg kg^{-1}	=	Milligram per kilogram
B:C	=	Benefit cost ratio	min.	=	Minimum
C.D.	=	Critical difference	mm	=	Millimeter
CEC	=	Cation exchange capacity	Mn	=	Manganese
cm	=	Centimeter	MSS	=	Mean sum of square
cm hr^{-1}	=	Centimeter per hour	Mt	=	Million tonne
Cu	=	Copper	N/N_2	=	Nitrogen
d.f.	=	Degree of freedom	No.	=	Number
DAP	=	Di-ammonium phosphate	NS	=	Non-significant
DAS	=	Days after sowing	P/P_2O_5	=	Phosphorus
dSm^{-1}	=	Deci siemens/meter	pH	=	pH of 1:2, soil : water suspension
DTPA	=	Diethylene Triamine Penta-acetic Acid	ppm	=	Part per million
EC	=	Electrical Conductivity	PSB	=	Phosphate solubilizing bacteria
et al.	=	(et alibi) or elsewhere	q ha^{-1}	=	Quintal per hectare
Fe	=	Iron	R.H.	=	Relative humidity
Fig.	=	Figure	₹	=	Rupees
FYM	=	Farmyard manure	S.No.	=	Serial Number
g	=	Gram	SEm ±	=	Standard error of mean
ha	=	Hectare	sq.m.	=	Square meter
hr	=	Hour	t ha^{-1}	=	Tonnes per hectare
i.e.	=	That is	Temp.	=	Temperature
K/K_2O	=	Potassium	var.	=	Variety
kg ha^{-1}	=	Kilogram per hectare	*viz.*	=	(Videlicet) Namely
m	=	Meter	Zn	=	Zinc

ACKNOWLEDGEMENT

*First of all I pray obeisance to **"Lord Ganesh ji"** with whose grace and blessing, I could be able to accomplish this task.*

*I feel proud privilege in expressing my deep sense of gratitude and indebtedness to my learned advisor **Dr. Mahendra Sharma,** Retired Professor, Department of Soil Science and Agriculture Chemistry, for his valuable guidance, constructive suggestions, keen and sustained interest and incessant encouragement bestowed during the entire period of investigation, as well as critically going through the manuscript.*

*I am extremely grateful to **Dr. Dilip Singh**, Dean, Rajasthan College of Agriculture, Udaipur, **Dr. R.H. Meena**, Associate Prof.& Head, Department of Soil Science and Agriculture Chemistry and All staff of student section for providing the necessary facilities and valuable guidance during the course of investigations.*

*I am gratified to acknowledge my thanks to the members of advisory committee; **Dr. H. S. Purohit,** Emeritus Prof., Department of Soil Science and Agriculture Chemistry, **Dr. Virendra Nepalia,** Retired Prof., Department of Agronomy, **Dr. B. Upadhyay**, Professor & Head, Department of Statistics and **Dr. Natwar Singh**, Prof. and Head Department of Genetics and Plant Breeding (DRI Nominee) RCA, Udaipur for their generous gestures and valuable suggestion in planning and execution of this study.*

*I feel short of words to express my deepest sense of gratitude to my teachers, **Dr. D.P. S. Dudi, Dr. Gajanand Jat, Dr. S.C. Meena, Dr. K.K. Yadav** and other staff members of Department of Soil Science and Agriculture Chemistry for their kind cooperation and help as and when needed.*

*Down the memory lane, I am very much thankful to **Shri S.N. Sharma,** Deputy Director**, Mr. Jinendra Mathur,** J.S.A.**, Dr. Sukhram Meena (ARO), Dr. M.K. Yadav, (**AARO), **Dr. Dharmendra Shekhawat (**AARO), **Mr. Divakar,** Lab assistant **and all staff member of SPTL, Udaipur,** I wish to accord my cordial thanks to my seniors **Dr. Rahul Chopra, Dr. Kavita Budaniya, Dr. Urmila Choudhary,** and my friends **Sushila Vishnoi, Pramendra, Deepak, Giriraj Gupta, Dr Bajrangbali, Kishan Gurjar, Devendra Verma** and loving Juniors **Sunita Kadwasra, Anil Mawalia** their very kind help during this task.*

*My word power fails to express my heartfelt gratitude and deep sense of obligation to my parents **Sh. Bhagirath Singh & Smt. Manohari Devi,** my **in-laws** and my husband **Anil Poonia,** my Brothers **Sharwan, Bhanwarlal** Sisters **Parwati, Kavita** Lovely child **Kuldeep, Aditya** and all other family members who continuously uplifted my moral spirit and love, affection, blessings, believe, enduring patience and persistent encouragement.*

*It is my unique privilege and duty to express sincere gratitude and regards to **Shri Pramod Kumar, Joint Director** of Division Sikar, **Dr. Maniram (ARO)** and **all staff member of STL, Sikar** without whose encouragement, I could not have completed this task.*

Last but not least a billion thanks to one and all well wishers associated with me directly and indirectly, whom I cannot forget forever.

Date : *19 /01/2021*
Place : *Udaipur* ***Subhita Kumari***

1. INTRODUCTION

The challenge for agriculture over the coming decades will be to meet the world increasing demand for food in sustainable way. To become weaker soil fertility and mismanagement of plant nutrient have made this task more difficult to complete vision 2020. Wheat (*Triticum aestivum* L.) belongs to family Poaceae is one of the most important cereal crops of the world. Among the world's most important food grain, it ranks next to rice. It is eaten in various forms by more than one billion in the world. Wheat straw is a good source of feed for a large population of the cattle in our country. Wheat has a relatively high content of niacin and thiamine that is why, wheat proteins are of special significance which are principally concerned in providing the 'gluten' which provides the frame work for sponge cellular texture of bread and baked products.

Wheat ranks first in the world among the cereals both in respect of acreage 219.51 m ha and production of 758.02 mt (United States Department of Agriculture, 2018). In India, the wheat production is about 106.21 mt from an area of around 29.9 m ha (Anonymous, 2019-20). In Rajasthan production of wheat is about 13.8 mt from an area around 3.5 m ha (Anonymous, 2018-2019). Although India is well placed in meeting out its needs for food grains and the major objective of nutritional and food security for entire population has not been achieved. The demand for food grains is expected to rise not only as a function of population growth but also as more and more people cross the poverty line with economic and social development. Most of the increase in production will have to come from the increased productivity, as the cultivated area under wheat is not expected to expand any further. The efficient input management and varietal improvement are two basic aspects that can help in achieving the future target. Wheat is the good supplement for nutritional requirement of human body as it contains 9-12% protein and 65-70% carbohydrates and it's by product (straw) is also used as dry fodder for animals.

The integrated use of organic materials and chemical nitrogenous fertilizers has received considerable attention in the past with a hope of meeting the farmer's economic need as well as maintaining favorable ecological conditions on long-term basis (Kumar *et al.*, 2007). The organic sources with fertilizers and bio-inoculants help to restore and sustain fertility and crop productivity. It also helps to check the emerging deficiency of nutrients other than N, P and K. Further, it brings economy and efficiency in fertilizers. The integration of fertilizers and organic sources with biofertilizers favorably affects the physical, chemical as well as biological environment of soils. Integrated use of mineral fertilizers together with organic manure and biofertilizer in suitable combination compliments and each other to optimize input use and maximize production and sustain the same without impairing the crop quality or soil health. It enables gainful utilization of organic wastes (Dhaka *et al.,* 2012).

The use of organics in an integrated way renders the benefits through, the maintenance of soil fertility and plant nutrient supply at optimum level for sustaining the desired productivity. This is achieved, through the optimum benefits of all possible sources of plant nutrients in integrated manner so as to attain the maximum yield without any effect on physical, chemical and biological soil properties. The major components of organic integrated nutrient management system involves the organic manures with variable nutrient release patterns mainly FYM, vermicompost, crop and bio-fertilizers along with natural soil reserves. Farmyard manure improves the physical condition of soil by increasing water holding capacity for maximum utilization of water. It also improves the chemical and biological properties of soil by increasing the cation exchange capacity and providing various hormones, vitamins and organic acids that are important for soil aggregation and for beneficial micro-organism which are involved in various biochemical processes and release of nutrients. The vermicomposting is an eco-friendly and effective way to recycle agricultural and kitchen wastes. The application of vermicompost not only adds plant nutrients (macro and micro) and growth regulators to one but also increases soil water retention, microbial population, humic substances of the soil, mineralization and release of nutrients (Alam *et al*., 2014).

Vermicompost has been recognized as a low cost and environmentally sound process for treatment of many organic wastes. Bevacqua and Mellano (2013) reported that vermicompost treated soils had lower pH and increased levels of organic matter, primary nutrients, and soluble salts. Edwards and Burrows (2010) reported that vermicompost, especially those from animal waste sources, usually contained more mineral elements than commercial plant growth media. Besides these, vermicompost also improves soil aeration, reduction of soil erosion, reduces of evaporation losses of water, accelerates the process of humification, stimulates the microbial activity, deodourification of obnoxious smell, destruction of pathogens, detoxification of pollutant in soil etc. (Kumar *et al*., 2015).

Azotobacter bacteria utilize atmospheric nitrogen gas for their cell protein synthesis. This cell protein is then mineralized in soil after the death of *Azotobacter* cells thereby contributing towards the nitrogen availability of the crop plants. *Azotobacter* spp. is sensitive to acidic pH, high salts, and temperature. *Azotobacter* has beneficial effects on crop growth and yield through, biosynthesis of biologically active substances, stimulation of rhizospheric microbes, producing phyopathogenic inhibitors, modification of nutrient uptake and ultimately boosting biological nitrogen fixation. Besides being quite expensive and making high cost of production, chemical fertilizers have adverse effect on soil health and microbial population. In such situation, biofertilizer can be the best alternative for enhancing soil fertility. Being economic and environmental friendly, biofertilizers can be used in crop production for better yield. Similarly, microbial products are considered safer, self-replicating, target specific, which is regarded as major component of integrated nutrient management from soil sustainability perspective. Use of biofertilizers such as biological nitrogen fixing and phosphate solubilizing micro-organisms is also gaining importance since biofertilizers are cost effective, eco-friendly and renewable source of plant nutrient to supplemental chemical fertilizers (Kumar and Urmila, 2018).

The presence of *Azotobacter spp*. in soils has beneficial effects on plants, but the abundance of these bacteria is related to many factors, soil physico-chemical (*e.g.* organic matter, pH, temperature, soil moisture) and microbiological properties. Its abundance varies as per the depth of the soil profile. *Azotobacter* is much more abundant in the rhizosphere of plants than in the surrounding soil and that this abundance depends on the crop spp. The role of biofertilizers is perceived as growth regulators besides biological nitrogen fixation collectively leading to much higher response on various growth and yield attributing characters (Saiyad, 2014). Therefore judicious combination of FYM, vermicompost, chemical fertilizers and bio-fertilizers facilitate profitable and sustainable production of wheat.

The information about different sources and combination of organic manures and inorganic fertilizer on growth and yield of wheat is scanty in Rajasthan. The response of organic sources of nutrients are also vary depending upon soil fertility and is highly location specific. With this background, a field trial, entitled **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** was planned with the following mentioned objectives:

1. To study the effect of fertility level, organic source and bio-inoculants on yield and yield attributes of wheat.
2. To assess the effect of fertility level, organic source and bio-inoculants on nutrient content and uptake of wheat.
3. To evaluate the effect of fertility level, organic source and bio-inoculants on soil fertility status.

2. REVIEW OF LITERATURE

A brief review pertaining to research work done on **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** during two consective *rabi* seasons of 2015-16 to 2016-17 are being presented in this chapter. Since the research work done on effect of fertility levels, organic sources and bio-inoculants on productivity of wheat and soil microbial properties are meager, references on other field crops have also been carefully included to elucidate the point related to present investigation.

2.1 EFFECT ON YIELD ATTRIBUTES AND YIELD

Singh and Singh (2001) conducted an experiment and reported that application of farmyard manure @ 5 and 10 t ha^{-1} significantly increased the grain and stover yield of wheat crop. Agrawal *et al.* (2003) reported that the application of vermicompost in all treatments significantly increased the total biomass production and yield of wheat plant over its control. Application of 75% VC and 25% FYM showed best results. Thus use of VC in combination with FYM is recommended for higher wheat production.

Jain *et al.* (2004) reported that the application of 125% RDF + PM increases the plant height (86.12 and 86.18 cm, respectively) and number of pods per plant (70.64 and 70.55) of wheat.

Afzal *et al.* (2005) reported that phosphate solubilizing micro-organism (PSM) in combination with phosphorus fertilizer and organic manure significantly improved grain and biological yield of wheat.

Kler and Walia (2006) observed that application of FYM @ 20 t ha^{-1} in wheat resulted in higher plant height, dry matter accumulation and grain yield compared to recommended dose of fertilizer.

Ram and Mir (2006) reported that the application of 10 t FYM + 120 kg N ha^{-1} significantly increased plant height, effective tillers m^{-1} row length, grains spike^{-1}, grain and straw yields over the control and 10 t FYM + 100 kg N ha^{-1}. Both biofertilizers, *i.e. Azospirillum* and *Azotobacter,* significantly enhanced all the growth parameters and grain and straw yields over the control. Combined application of *Azospirillum* + *Azotobactor* showed significant improvement over their individual application.

Behera *et al.* (2007) reported that the application of FYM @ 10 t ha^{-1} and poultry manure @ 2.5 t ha^{-1} along with 50% NPK resulted in 13.5 and 22.9% high yield respectively over 50% NPK alone.

Singh *et al.* (2007) reported that the application of biofertilizers (*Azospirillum* and *Azotobactor*) significantly increased number of tillers m^{-2}, ear length, number of grains ear^{-1}, test weight and yield of wheat grain and straw compared to control during both the years.

Channabasanagowda *et al.* (2008) reported that application of vermicompost @ 3.8 t ha^{-1} + poultry manure @ 2.45 t ha^{-1} in wheat recorded significantly higher plant height, number of leaves, 1000 seed weight) and seed yield (3043kg ha^{-1}), vigour index (3223) and seedling dry weight (311.27 mg) compared to other treatments.

Ramesh *et al.* (2008) conducted an experiment on effect of organic manures on productivity, soil fertility and economics of soybean (*Glycine max*) - durum wheat (*Titicum durum*) cropping system under organic farming in Vertisols. They reported that the in the first year (2003-04), chemical fertilizers recorded significantly higher yield of crops and application of organic manures recorded 7.3 to 13.3 % reduction in soybean yield and 7.8 to 14.8 % reduction in wheat yield. In the second year (2004-05), soybean yield was at par among the nutrient sources and wheat yield was at par between chemical fertilizers and poultry manure treatment. In the third year (2005-06), application of organic manures recorded similar yields to that of chemical fertilizers and in fact, poultry manure application resulted in 17.5 and 3.2 % higher yields of soybean and wheat, respectively, over the chemical fertilizers.

Singh *et al.* (2008d) conducted a field experiment during 2003-04 and 2004-05 at Jodhpur. The results showed that integrated use of FYM @ 7.5 t ha^{-1} + 50% RDF (50 kg N + 13.5 kg P ha^{-1}) + biofertilizers (*Azotobactor* + PSB) in wheat – based cropping sequence recorded significantly highest grain yield, net returns and B: C ratio of crop over control.

Bandyopadhyay *et al*. (2009) conducted an experiment on efficient utilization of limited available water in wheat through proper irrigation scheduling and integrated nutrient management under different cropping system in a Vertisols. They reported that application of 100% NPK significantly improved the grain yield of wheat by 21.5% over application of 75% NPK application.

Malik *et al.* (2009) conducted an experiment on organic amendment influence on soil organic pools and crop productivity in a nineteen years old rice-wheat agro-ecosystem. They reported that the biofertilizer application significantly improved grain yield and straw yield of wheat over un-inoculated plots.

Sharma *et al.* (2009) reported that the yield and yield attributing characters of wheat were found maximum with the application of 75% NPK + 25% N supplied with FYM + biofertilizer. The highest net return and net return/rupee invested in wheat was found with the application of 75 NPK + 25% N with FYM + biofertilizer.

Behera (2009) conducted an experiment on organic manuring for soil biological health and productivity of a wheat-soybean cropping system in the Vertisols of central India. He reported that grain yield of wheat was significantly increased with PM at 2.5-10 t ha^{-1} or FYM at 10-20 t ha^{-1} compared with the control. However, the highest productivity was obtained with PM at 10 t ha^{-1}, which even performed better than NPK, indicating that NPK fertilizers alone did not provide adequate and balanced nutrition for potential yield of the crop.

Kotangale *et al.* (2009) conducted a field experiment at (CRS) Akola and observed that significantly higher grain yield of wheat was observed in 100% RDF + 10 t FYM ha^{-1} followed by 100% RDF.

Dubey *et al.* (2010) conducted an experiment on grain yield of wheat as effect by growth promoting bacteria. They reported that the application of the growth promoting bacteria might have the potential to be used as a biofertilizer for wheat crop.

Jaga and Singh (2010) reported that the *Azotobactor* supplied additional nitrogen in an eco-friendly manner and plays a vital role in wheat. Hence, *Azotobactor ization* has synergistic effect on yield. Generally with the application of *Azotobactor,* the yield of agriculture crops is increased by 10-12 %.

Chauhan *et al*. (2011a) reported that the use of farmyard manure 15 t ha^{-1} + 100% NPK increases the yield of wheat crop as compared to the use of 75% NPK + 15% farmyard manure.

Devi *et al.* (2011) carried out an experiment and revealed that the application of 100% recommended dose of fertilizers (RDF) *i.e.* 120:26.4:50 N:P:K kg ha^{-1} + vermicompost @ 1.0 t ha^{-1} + phosphate solubilizing bacteria (PSB) and 75% RDF + vermicompost @ 1.0 t ha^{-1} + PSB produced higher yield attributes and grain yield of wheat than the other treatments.

Katiyar *et al.* (2011) conducted an experiment on effect of *Azotobactor* and nitrogen levels on yield and quality of wheat. They reported that wheat seed was inoculated with *Azotobactor* it increases the yield up to 1.92 – 2.0 % as compared to non-inoculated seed.

Sandal *et al.* (2011) conducted an experiment at Himachal Pradesh and showed that increasing the dose from 50 to100 % of recommended NPK (80:17:30 kg ha^{-1}) observed significantly higher plant height, dry matter accumulation and yield of rainfed wheat over control.

Thakur *et al.* (2011) conducted an experiment on impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. They reported that the application of recommended dose of N, P and K (120:80:40 kg ha^{-1} to wheat) with organic manure @ 15 t FYM ha^{-1} resulted in 292% increase wheat yield over control.

Davari *et al.* (2012) conducted an experiment on the effect of combinations of organic materials and biofertilisers on productivity, grain quality, nutrient uptake and economics in organic farming of wheat. They reported that combinations of FYM + RR + B and VC + RR + B resulted in the highest increased growth and yield attributing characters of wheat and increased grain yield of wheat over the control by 81% and 89% (Year 1 & Year 2), and net return by 82% and 73% .

Kaushik *et al.* (2012) reported that the combined application of 3.0 t vermicompost + RDF along with *Azospirillum* + *PSB* recorded significantly higher number of effective tillers $plant^{-1}$ (4.92), grains ear^{-1} (49.05) grain (57.64 q ha^{-1}) and straw (74.46 q ha^{-1}) yields over vermicompost 1.5 and 3.0 t along with no inoculation.

Malghani *et al*. (2012) conducted an experiment at Karor-Layyah, Punjab. Result showed that application of 175-150-125 NPK kg ha^{-1} recorded significantly higher growth parameters *viz.* plant height and dry matter accumulation of wheat over control.

Meena *et al.* (2012) reported that the integrated use of NPK and FYM (7.5 t ha^{-1}) gave significantly higher grain yield (5.23 t ha^{-1}) as compared with general recommended dose of NPK (4.28 t ha^{-1}).

Singh *et al.* (2012c) reported that the application of *Azotobacter* strain (Azo - 8) along with urea (60 kg N ha^{-1}) and farm yard manure (40kg N ha^{-1}) gave the best response. It resulted in more than 23% and 36% increase in shoot fresh weight and dry weight, 26% and 38% increase in root fresh weight and dry weight, 39% increase in test weight of seeds and 27% increase in yield over control in wheat crop.

Singh *et al.* (2012b) reported that the growth parameters were affected significantly by the application of FYM and vermicompost in wheat crop. Increasing the doses of vermicompost increased dry matter accumulation, LAI and LAD. All the growth parameters were recorded maximum with vermicompost N_{250} followed by vermicompost N_{200} and vermicompost N_{150} and FYM.

Chesti *et al*. (2013) conducted an experiment on effect of integrated nutrient management on yield of and nutrient uptake by wheat (*Triticum aestivum*) and soil properties under intermediate zone of Jammu and Kashmir. They reported that the application of 100% NPK +10 t FYM ha^{-1} significantly increases the grain yield (4.92 t ha^{-1}) of wheat.

Choudhary *et al.* (2013) conducted an experiment and reported that the application of 50% RDF + VC @ 2 t/ha recorded significant increase in dry matter accumulation $meter^{-1}$ row length (364.5g), yield attributes *viz.* spike length (10 cm), no. of spikes $meter^{-1}$ row length (81.6), grains $spike^{-1}$ (48.9) and test weight (43.0 g) as well as grain (5.48 t ha^{-1}) and straw yield (7.85 t ha^{-1}).

Meena and Meena (2013) reported that the grain and straw yield of wheat increased with the application of N and poultry manure individually, yield also increased with the combined application of N and poultry manure.

Sharma *et al.* (2013) reported that the substitution of 25% NPK through farmyard manure in recommended dose of NPK along with 5 kg Zn ha^{-1} and *PSB* + *Azotobacter* recorded significantly higher grain yield (58.23 q ha^{-1}) over the 100% NPK treatment (49.79 q ha^{-1}).

Singh *et al.* (2013) conducted an experiment on effect of integrated nutrient management practices on soil health and economics of wheat. They reported that the grain yield was significantly higher in the treatment 125% NPK and it was found statistically at par with 75 % NPK + VC 3 t ha^{-1}, 75 % NPK + VC 1.5 t ha^{-1} + 10 t ha^{-1} FYM, 100 % NPK and 75 % NPK + FYM 20 t ha^{-1}.

Shukla *et al.* (2013) conducted an experiment on effect of vermicompost and microbial inoculants on soil health, growth and yield of HD 2687 wheat. They observed that the maximum grain yield of 3.11 q ha^{-1} was obtained in plots amended with vermicompost (6 t ha^{-1}) and co-inoculated with *Azospirillum* and *Azotobacter.*

Arif *et al.* (2014) conducted an experiment on effect of integrated use of organic manures and inorganic fertilizers on yield and yield components of rice. The results showed that organic and inorganic manures in combination increased the plant height, fertile tillers per hill, number of grains per panicle, panicle length, number of panicles per hill, 1000-grain weight, biological yield, grain yield and harvest index. Maximum number of fertile tillers per plant (16.79), number of panicles per hill (8.41), 1000- grain weight (21.12 g), biological yield (10.19 t ha^{-1}), grain yield (4.47 t ha^{-1}) and harvest index (43.76%) were recorded from the plots receiving poultry manure @ 10 t ha^{-1} in combination with 50% of RDF. This was followed by 100% RDF. It is evident that yield of rice can be increase significantly with the combined use of organic manure with chemical fertilizers.

Chauhan (2014) conducted an experiment and revealed that 100% RDF (120 Kg N+ 60 Kg P_2O_5 + 40 Kg K_2O ha^{-1}) recorded significantly highest plant height (92.4 cm), effective tillers (330.0 m^2), length of ear (8.6 cm), grain ear^{-1} (8.6), grain weight ear^{-1} (41.5 g) and test weight (53 g).

Khan and Khalil (2014) conducted an experiment on integrated use of organic and inorganic fertilizers in wheat and their residual effect on subsequent mung bean. They reported that the poultry manure, farm yard manure and nitrogen significantly affected spikes m^{-2} grain yield and harvest index of wheat. Higher spikes m^{-2}, grain yield was observed with application of 6 tons poultry manure, 6 tons farm yard manure ha^{-1} and 90 kg N ha^{-1} while higher harvest index was recorded in control.

Patel *et al.* (2014) reported that application of organic manures, *i.e.*, FYM @10 t ha^{-1} and vermicompost 5 t ha^{-1} with 60 kg P_2O_5 ha^{-1} or 40 kg P_2O_5 ha^{-1} + PSB and 40 kg S ha^{-1} produced maximum wheat grain and straw yield.

Verma *et al.* (2014) reported that the application of recommended dose of fertilizers + vermicompost @ 5.0 t ha^{-1} + *Azotobacter* and PSB as seed treatment and sprayed at 1st and 2nd irrigation registered highest grain yield (56.70 q ha^{-1}) of wheat followed by RDF + vermicompost @ 5.0 t ha^{-1} + *Azotobacter* and PSB as seed treatment sprayed under 1st irrigation (55.55 q ha^{-1}), RDF + FYM 10.0 t ha^{-1} + *Azotobacter* and PSB as seed treatment (55.32 q ha^{-1}) were significantly at par, RDF + vermicompost @ 5.0 t ha^{-1} + Strain of *Azotobacter* and PSB (54.39 q ha^{-1}) differed significantly and lowest grain yield (46.29 q ha^{-1}) of wheat was recorded under only RDF treatment (control).

Chopra *et al.* (2016) conducted an experiment at Udaipur and observed that the enrichment of soil with 5 t ha^{-1} poultry manure + 75% NPK + dual inoculation of *Azotobactor* + PSB significantly increased the effective tillers per m row length, number of grains per ear, test weight, grain, straw and biological yield of wheat.

Aatif *et al.* (2017) conducted an experiment and found that FYM at 9 t ha^{-1} significantly affected spike length, grains per spike and grain yield of wheat, however, control plots resulted in lower number of grains per spike, spike length and grain yield.

Singh and Singh (2017) conducted an experiment at Agra and reported that application of 120 kg N ha^{-1} and 7.5 t FYM ha^{-1} significantly increased the grain and straw yield of wheat as compared to 80 kg N ha^{-1} and 5.0 t FYM ha^{-1}.

Singh *et al.* (2018) conducted an experiment at Fatehgarh Sahib and observed that the improvement in yield attributes and yield of wheat was recorded with the application of 100% RDF + Vermicompost (2 t ha^{-1}) + PSB which was at par with the application of 75% RDF + Vermicompost (2 t ha^{-1}) + PSB and 100% RDF + Vermicompost (2 t ha^{-1}).

Meena *et al.* (2018) carried out an experiment and reported that grain and straw yield of wheat increased significantly in the treatments where farmyard manure (FYM) was applied either alone, or in combination with inorganic fertilizer as compared to control.

Maurya *et al.* (2019) conducted an experiment at Faizabad and observed that significantly higher grain and straw yield of wheat were found under incorporation of 125% recommended dose of fertilizer + 25% N through vermicompost, however, highest harvest index was recorded under application of 100% RDF + 25% through FYM, while highest net return and benefit: cost ratio was observed under 100% RDF + 25% through vermicompost.

Borse *et al.* (2019) conducted an experiment at Navsari and found that application of FYM @ 10 t ha^{-1} and higher dose of fertilizer i.e.120 % RDF (216-108-00 kg NPK ha^{-1}) recorded significantly higher effective tillers, spike length, spikelets per spike, grains per spike, grain and straw yield of wheat crop. The net returns ha^{-1} and BCR were maximum under FYM @ 10 t ha^{-1} and 120% RDF treatments, respectively.

Kavinder *et al.* (2019) conducted an experiment at Hisar and revealed that application of 15 t ha^{-1} FYM along with 120 kg N ha^{-1} significantly improved the number of tillers per m row length, grain, straw and biological yield of wheat.

2.2 EFFECT ON NUTRIENT CONTENT AND UPTAKE

Singh and Singh (2005) reported that the organic manures significantly increased the uptake of N, P and K in grain and straw and their total uptake, grain and straw yields and protein content in grain over the control treatment. Among various organic sources, FYM at 15 t ha^{-1} recorded the highest N, P and K uptake in straw yield and protein content in grain of wheat.

Shah and Ahmad (2006) reported that the N uptake in grain (47.66 kg ha^{-1}) and straw (19.28 kg ha^{-1}) of wheat was also significantly greater in treatments receiving 75 or 50 % N from urea and 25 or 50% from FYM.

Sharma *et al.* (2006) reported that the highest uptake of N, P and K were obtained with 150 kg N ha^{-1} + FYM + *Azotobacter* and adequate irrigation in wheat crop.

Mehra and Singh (2007) reported that the integrated nutrient management involving the combination of FYM, green manure, crop residue and biofertilizer (*Azotobacter*) with inorganic sources resulted in highest N (144.99 kg ha^{-1}), P (36.40 kg ha^{-1}) and K (145.40 kg ha^{-1}) uptake by wheat.

Kushare *et al.* (2009) reported that the combined inoculation of biofertilizer yielded maximum grain yield (26.06 q ha^{-1}) and straw yield (33.69 q ha^{-1}). Interaction effect showed that application of 60:30 kg N: P ha^{-1} (75% RDF) coupled with combined inoculation registered significantly higher grain yield (30.96 q ha^{-1}) of wheat with higher net profit, B: C ratio than those with 80:40 kg N:P/ha (100% RDF) without biofertilizer inoculation. Thus 25% saving in nitrogen and phosphorus application could be possible with combined inoculation of *Azotobactor* + PSB.

Pandey *et al.* (2009) reported that addition of organic manure (l0 t ha^{-1} FYM) with fertilizer levels significantly increased the nutrient uptake by wheat.

Rather and Sharma (2010) conducted an experiment on effect of integrated nutrient management on productivity and nutrient uptake in wheat and soil fertility. They reported that the maximum nutrient uptake was noticed due to 100% RDF of NPK+VC+Zn+PSB and minimum with control.

Singh and Kumar (2010) reported that the highest value of nutrient content and uptake in wheat found with the application of 75% NPK + vermicompost @ 3 t ha^{-1} + foliar spray of $ZnSO_4$ (0.5%) at 30 DAS and 75% NPK + FYM at 10 t ha^{-1} + foliar spray of $ZnSO_4$ (0.5%) at 30 DAS.

Katiyar *et al.* (2011) conducted an experiment on effect of *Azotobactor* and nitrogen levels on yield and quality of wheat and reported that the significant increase in N content of grain due to inoculation with *Azotobactor* (1.92 and 2.0%) with mixed strain as compared to un-inoculated control (1.82 and 1.90%).

Singh *et al.* (2011b) reported that the combined application of organic manures and inorganic fertilizers increased the NPK uptake by wheat crop compare to treatment T_2 where full dose of NPK applied through urea, single superphosphate and murate of potash.

Devi *et al.* (2011) conducted an experiment and revealed that the application of 100% recommended dose of fertilizers (RDF) *i.e.* 120:26.4:50 N:P:K kg ha^{-1}+ vermicompost @1 t ha^{-1} + phosphate solubilizing bacteria (*PSB*) and 75% RDF + vermicompost @1 t ha^{-1}+ *PSB* produced higher yield led to higher NPK uptake by wheat.

Davari *et al*. (2012) conducted an experiment on the effect of combinations of organic materials and biofertilizers on productivity, grain quality, nutrient uptake and economics in organic farming in wheat. They reported that the combinations of FYM + RR + B and VC + RR + B improved grain quality and nutrient uptake by grain.

Shah *et al.* (2012) conducted an experiment on enhancing soil fertility and wheat productivity through integrated nitrogen management. They observed that among integrated application of N sources, 25% poultry manure + 75% mineral N source resulted in the greatest N uptake by grain and straw of wheat.

Sharma (2013) conducted an experiment on effect of long term integrated nutrient management system on soil and crop productivity in rice wheat crop sequence and reported that the application of 100% NPK increases the NPK uptake by wheat.

Sharma *et al.* (2013) reported that maximum nutrient (N, P, K, S and Zn) uptake by wheat 147.08, 28.44, 174.6, 51.94 kg ha^{-1} and 335.6 g ha^{-1}, respectively were observed in the treatment receiving 75% NPK + 5t FYM ha^{-1} + PSB + *Azotobactor* + Zn.

Singh *et al.* (2013) conducted an experiment on integrated nutrient management in rice and wheat crop in rice- wheat cropping system in lowlands and reported that the uptake of N (91.6 kg ha^{-1}), P (18.9 kg ha^{-1}) and K (109.3 kg ha^{-1}) by wheat was maximum with 100% NPK + 5 t FYM ha^{-1} followed by 75% NPK + 5 t FYM ha^{-1}. The content of organic carbon, available P and K in soil was improved with combined use of fertilizers as compared to 100% NPK, however, magnitude of increase was higher in 15 t FYM ha^{-1}.

Singh and Singh (2017) conducted an experiment at Agra and reported that application of 120 kg N ha^{-1} and 7.5 t FYM ha^{-1} significantly increased the protein content, uptake of N, P, K, S and Cu by wheat as compared to 80 kg N ha^{-1} and 5.0 t FYM ha^{-1}.

Meena *et al.* (2018) carried out an experiment and reported that nutrient uptake (N, P and K) by wheat increased significantly in the treatments where farmyard manure (FYM) was applied either alone, or in combination with inorganic fertilizer as compared to control.

Maurya *et al.* (2019) conducted an experiment at Faizabad on wheat and observed that significantly higher nitrogen uptake by grain at harvest was recorded with 100% RDF + 25% Vermicompost which was at par with 100% RDF +25% Biocompost, 125% RDF + 25% FYM, 125% RDF + 25% Biocompost, 125% RDF + 25% Vermicompost while in case of nitrogen uptake by straw, recorded highest with

125% RDF + 25% vermicompost which was at par with 100% RDF +25% Biocompost, 100% RDF+25% vermicompost, 125% RDF + 25% FYM, 125% RDF + 25% Biocompost and significantly superior over rest of the treatments.

Borse *et al.* (2019) conducted an experiment at Navasari and reported that FYM @ 10 t ha^{-1} and 120 % RDF recorded significantly highest protein content, total nitrogen, phosphorus and potassium uptake by wheat compared to other treatments.

2.3 EFFECT ON SOIL FERTILITY STATUS

A long term fertilizer experiment conducted at Bhopal indicated that application of 100% NPK + green manure or FYM was significantly superior over 150% NPK. The soil organic carbon, available micronutrients (Zn and Mn) significantly increased by application of NPK with FYM over rest of the treatments. Similar trend was also observed in case of available P and K status of soil (Swaroop and Yaduvanshi, 2000). Laxminarayan (2006) conducted a field experiment on altisols of Mizoram for three consecutive *kharif* seasons during 1998-2000 and found that the application of FYM along with chemical fertilizers resulted in highest organic carbon content of soil. He further reported that the integrated application of FYM, poultry manure or pig manure along with recommended dose of NPK resulted in a progressive improvement in organic matter content of the soil.

Yadav *et al.* (2003) at Jodhpur reported that significantly higher organic carbon was obtained in the plots supplied with 10 tonnes FYM ha^{-1} either alone or in combination with inorganic fertilizer compared with the control and was statistically at par with 10 tonnes ha^{-1} mustard siliquae straw compost. Dikshit and Khatik (2002) conducted an experiment at Jabalpur (M.P.) reported that available N, P and K contents in soil were significantly enhanced with organic as well as inorganic source of plant nutrients (50% recommended dose of fertilizer + 10 t FYM ha^{-1}) than initial soil status.

At Hisar, Sharma *et al.* (2007) observed significant increase in available N, P, K and organic carbon by application of integrated nutrient treatments to wheat. Available N content increased compared with its initial soil status under integrated nutrient treatments *i.e.* 187.5 kg N ha^{-1} + FYM (10 t ha^{-1}) + *Azoztobacter* and 150 kg N ha^{-1} + FYM (10 t ha^{-1}) + *Azotobacter.* The content of organic carbon, available phosphorous in soil increased and bulk density, pH decreased in all the nutrient management practices involving FYM 10 t ha^{-1}. Singh *et al.,* (2008) conducted an experiment at Jodhpur and reported that integrated use of FYM @ 7.5 t ha^{-1} + 50% RDF (50 kg N + 13.25 kg P ha^{-1}) + biofertilizer (*Azotobacter* + PSB) in wheat recorded significantly the maximum gain in available N and P status and resulted in significantly highest Yield and nutrient uptake by *kharif* crops (green gram, cluster bean and pearl millet) due to residual effect of FYM applied either alone or in combination.

On a loamy sand soil in Haryana, Sharma *et al.* (2009) conducted an experiment on rice-wheat system and concluded that organic manures increased the organic carbon and NPK status of the soil with the application of 75% NPK +25% N supplied with FYM + biofertilizers. Rather and Sharma (2010) conducted a field experiment at Bulandshahar, U.P. and revealed that a significant improvement in soil properties and fertility status was found under 100% recommended NPK (120-60-40 kg ha^{-1}) + vermicompost + zinc + PSB. Organic carbon content of soil improved from 3.0 to 4.6 g kg^{-1} soil, Bulk density reduced from 1.50 to 1.32 Mg/m^3, available N, P, K and Zn improved in soil by the integration of organic with inorganic fertilizers. Thus, maximum available N (231.0 kg ha^{-1}), P (18.5 kg ha^{-1}), K (130.6 kg ha^{-1}) and Zn (1.64 mg kg^{-1}) was found in soil from integrated nutrient application.

Sepat *et al.* (2010) at New Delhi, observed that application of recommended dose of fertilizer *i.e.* 120-26.4–50 kg N-P-K ha^{-1} along with 5 tonne FYM ha^{-1} + biofertilizer (*Azotobacter*, PSB and VAM) + 25 kg $ZnSO_4$ ha^{-1} in wheat significantly increased the available NPK of soil over control. Jat *et al.* (2015) conducted a field experiment on rice-wheat system at Varanasi, Uttar Pradesh and revealed that integrated nitrogen management practices proved significantly superior to fertilizer alone. Higher value of NPK content in soil was obtained with organic treated source (FYM) than inorganic fertilizer. Application of 50% RND + 50% N as FYM + *Azospirillum* left higher amount of residual nutrients than to other treatments. This result confirm the findings of Paul *et al*. (2013).

Singh and Bhadoria (2013) carried out a field experiment on wheat at Morena and reported that organic carbon, available N and P content in soil after harvest of wheat was recorded highest with application of 150 kg N ha^{-1} in wheat and with application of biofertilizers. Experiment conducted on Inceptisols of Agra on wheat indicated that significant increase in available N, P and K status of soil upto 10 tonnes of FYM ha^{-1} over no FYM and reported that increase in N level from 60 to 120 kg ha^{-1} in wheat significantly increased the nutrient status of soil viz. available N, P, and K with subsequent increase to nitrogen from 60 to 120 kg ha^{-1} and also reported that application of biofertilizers as seed treatment to wheat crop significantly increased the available nitrogen content of soil at harvest of wheat over no inoculation treatment. However, available P and K contents did not show significant variation due to biofertilizers (Singh *et al*., 2013-a).

Bodruzzaman *et al.* (2010) reported that organic matter was reduced (13 to 19 %) with inorganic fertilizers and increased (7 to 13%) with organic manures while available phosphorus and exchangeable potassium was reduced in control and inorganic fertilizer treatments but increased in organic manures treatments in wheat-rice cropping system. An long term field experiment was conducted on a permanent plot at IGKV, Raipur to evaluate the effect of farm yard manure, green manure and composted rice straw with inorganic fertilizer on productivity and soil properties of rice-wheat cropping system and found that application of 50% RDF significantly increased the organic carbon available N, P and K status of soil over control (N_0 P_0 K_0), in-situ application of green manure along with 50% of recommended dose of fertilizer is the most favourable treatment to have highest available N (255 kg/ha) in surface soil. The results showed that available P content of soil increased significantly with farmyard manure, composted rice straw and green manure in conjunction with 50% recommended dose of fertilizer over initial value and control (Urkarkar *et al.,* 2010).

Mehta *et al.* (2007) reported that application of 5 t FYM ha^{-1} + 50% RDF significantly increased the organic carbon, available N, P and K in soil after harvest of wheat. Kumar, (2008) at New Delhi observed that application of 120 kg N ha^{-1} + 5 kg zinc ha^{-1} + 10 t FYM ha^{-1} increased organic carbon, N, P and K in maize-wheat cropping system. Pandey *et al.* (2009) at Pusa, samastipur, Bihar while working on late sown wheat observed that application of 150% RDF (180-39.3-50 kg NPK ha^{-1}) together with 10 t FYM ha^{-1} + 25 kg $ZnSO_4$ recorded highest organic carbon, available N, P and K and significantly reduced the bulk density of the soil as compared to chemical fertilizers alone.

Kidane, (2014) during an experiment at Hisar, revealed that residual effect of inputs manure (20 t ha^{-1}), 100% NPK and biofertilizer (*Azotobacter* and PSB) applied to preceding wheat significantly improved the available N, P, K and organic carbon and reduced the bulk density, EC of soil after harvest of both wheat and pearl millet. Inoculation of biofertilizer did not significantly influence OC and available N in soil after harvest of pearl millet. At Akola on typic haplustert soils, Katkar *et al.* (2011) carried out an experiment on long-term fertilizer use on sorghum- wheat system for twenty years and revealed that significantly highest soil organic carbon (6.77 g kg^{-1}) and total N (0.059%) were recorded in the treatment of application of farmyard manure at 10 tonnes ha^{-1} + 100% NPK (100-50-40) to sorghum and only mineral fertilizer (120-60-60) to wheat as compared to supra optimal dose of fertilizers (150% NPK).

Kumar *et al.* (2012) carried out an experiment at Hisar and revealed that continuous use of FYM, wheat straw and green manure in conjunction with fertilizers increased the soil organic carbon (OC), hydraulic conductivity, available N, P, K status and decreased soil bulk density, soluble salts and pH. Among organic materials, FYM resulted in highest OC (0.54%), available N (242.8 kg/ha), available P (17.7 kg/ha) and available K (318.5 kg/ha) level in soil under pearl millet-wheat cropping system. An experiment on maize-wheat cropping sequence was conducted by Manjhi *et al.* (2016) and reported that integration of organics along with NPK further improved the soil properties. Among three source of organics (FYM, cut paddy straw and green karanj leaves) FYM was found superior to others. FYM substitution up to 50% was observed to be the most effective INM practice as compared to other sources.

Kumawat, (2002) at Hisar, Haryana during an experiment reported that application of nitrogen from 0 to 120 kg N ha^{-1} to wheat crop significantly increased the available P content of soil from their initial status. Buildup in organic carbon, available N, P and K content in soil increased significantly due to FYM application in soybean-wheat cropping system at Jabalpur (Tiwari *et al*. 2002). Mankotia and Thakur (2009) reported that application of 5 t FYM ha^{-1} increased the available nitrogen in soil after harvest of wheat.

Moharana *et al.* (2012) conducted a six years pearl millet–wheat cropping system in an inceptisol of subtropical India. These results concluded that for sustainable crop production and maintaining soil quality, input of organic manure like FYM is of major importance and should be advocated in the nutrient management of intensive cropping system for improving soil fertility and biological properties of soils. Ghanshyam *et al.* (2010) at Hisar during an experiment revealed that application of FYM and vermicompost in greengram significantly increased the available N and P in soil after harvest of greengram, over no organic manure under greengram-wheat cropping system.

Sharma (2009) conducted an experiment at Bikaner and reported that application of 10 t sheep manure ha^{-1} and nitrogen application (at 100 kg N ha^{-1}) recorded significantly higher organic carbon, available N, P and K in soil after harvest of fodder oat. Meena *et al.* (2012-b) at New Delhi observed that conjoint use of fertilizer NPK and FYM, improved soil physical health as revealed by a significant decrease in soil bulk density (BD) and an increase in water holding capacity. Mukherjee, (2014) conducted an experiment at Kalingpong, West Bengal and reported that application of 10 t FYM ha^{-1} significantly increased the organic carbon, available N, P and K in maize-yellow sarson sequence.

Shaktawat and Shekhawat (2010) reported that application of FYM @ 10 t $ha^{-1}$with fertilizers 120 kg N + 60 kg P_2O_5 in barley significantly increased the available nitrogen, phosphorus and potassium content in soil as compared to control. Khambalkar *et al.* (2012) conducted an experiment in Gwalior on pearl millet-mustard cropping system and reported a marginal but significant declining trend on surface soil pH from the initial value under integrated nutrient treatments and observed that application of 100% NPK (80 kg N, 40 kg P_2O_5 and 20 kg K_2O ha^{-1}) + 10 t FYM ha^{-1} + *Azotobacter* + PSB recorded maximum soil organic carbon, available N, P and K.

Rajkhowa *et al.* (2003) reported that application of 100% (20 kg N, 40 kg P and 30 kg K ha^{-1}), 75% and 50% RDF with 2.5 t ha^{-1} vermicompost in greengram was found beneficial for improving organic carbon and N, P and K status of soil over initial value. Highest organic carbon and available N, P and K content in soil at harvest was recorded with application of 100% recommended dose of fertilizer along with 2.5 t vermicompost ha^{-1}. Singh and Rai (2004) conducted a field experiment at New Delhi, on soybean and reported that application of 100% recommended dose of fertilizer + 5 t ha^{-1} FYM + crop residue incorporation + Zn (25 kg $ZnSo_4$ ha^{-1}) recorded maximum organic carbon (0.385%), available N (185.22 kg ha^{-1}), P (14.82 kg ha^{-1}) and K (202.03 kg ha^{-1}) at the end of crop sequence in soil.

Goyal (2002) at Udaipur observed that inoculation with *Azotobacter* had no significant effect on bulk density, porosity and water stable aggregates of soil after harvest of both the crops in maize– wheat crop sequence. It significantly improved the N and P status of soil, but K and DTPA extractable Zn, status of soil after the harvest of both crops was not affected.

Patidar and Mali (2002) during an experiment at Udaipur, recorded that available P status in soil after harvest of succeeding wheat significantly influenced due to residual effect of FYM, 75% and 100% recommended level of fertilizer (N and P) applied in preceding sorghum. Sharma and Manohar (2002) at Durgapura, Jaipur during an experiment reported that application of 40 kg S/ha significantly improved the available P and S content in soil after harvest of wheat and pearl millet. Application of nitrogen to wheat did not bring any change in grain and stover yields of succeeding pearl millet and soil fertility.

Yadav and Kumar (2002) in a long term experiment of rice-wheat recorded higher reduction in pH, EC and ESP of soil by using organic manure along with chemical fertilizers as compared to fertilizer alone. They also noted greater increase in available N and P content in the soil with integrated nutrient management. Verma *et al.* (2010) studied the effect of integrated nutrient management on major soil properties under maize-wheat cropping system and observed that application of FYM alone or in combination with fertilizers (100% NPK + 10 t ha^{-1} FYM) significantly increased the water stable aggregates after harvest of maize and wheat.

Singh *et al.* (2013-b) conducted a field experiment at Jobner, (Rajasthan) and reported that the combined application of inorganic fertilizers and manures or FYM alone in pearl millet significantly improved the organic carbon and available nitrogen in soil over control.

Kumar (2008) conducted an experiment at New Delhi on maize and observed that application of 120 kg N ha^{-1} + 26.2 kg P_2O_5 ha^{-1} + 41.5 kg K_2O ha^{-1} increased the available N, P and K content in soil over control.

Pandey *et al.* (2009) observed that application of 150% RDF together with 10 t FYM ha^{-1} + 25 kg $ZnSO_4$ ha^{-1} recorded highest organic carbon, available N, P and K content in soil after harvest of wheat crop.

Tetarwal *et al.* (2011) reported that significant built up of organic carbon (0.74%), available N (316.0 kg ha^{-1}) and available P (10.8 kg ha^{-1}) were registered with RDF + FYM 10 t ha^{-1} after harvest of maize.

Khambalkar *et al.* (2012) reported that application of 100% NPK + 10 t FYM ha^{-1} + *Azotobactor* + PSB recorded maximum soil organic carbon, available N, P and K in pearlmillet-mustard crop sequence.

Priyadarshani *et al.* (2012) conducted a field experiment at Gwalior, M.P. and observed that 100% NPK + 10 t FYM ha^{-1} + *Azotobactor* + PSB increased organic carbon, available N, P, K content in soil after harvest of pearlmillet.

Chesti *et al.* (2013) conducted a field experiment at Rajouri, Jammu and Kashmir and found that application of 100% NPK + 10 t FYM ha^{-1} recorded highest organic carbon, available N, P and K in soil after harvest of wheat.

Patil *et al.* (2014) at Anand, Gujarat reported that application of 50% RDN + 25% FYM + 25% castor cake + *Azospirillum* + PSB produced significantly higher organic carbon content, available nitrogen, phosphorus and potash content in soil after harvest of summer pearlmillet.

Singh *et al.* (2015) conducted a field experiment at Pantnagar, Uttrakhand and observed that application of 50% RDN through inorganic source + 50% through FYM significantly increased available N, P and K in soil after harvest of sweet sorghum.

Babar and Dongale (2011) conducted a field experiment on lateritic soils of Konkan and observed that application of 100% RDF of NPK through inorganic fertilizers improved the organic carbon content and content of N, P and K in soil under mustard-cowpea-rice cropping sequence.

2.4 EFFECT ON PHYSICO-CHEMICAL PROPERTIES OF SOIL

Abraham and Lal (2004) conducted an experiment and reported that the soil organic carbon showed increased values up to 0.58% as a result of application of farm compost (5 t ha^{-1}) in combination with poultry manure (0.5 t ha^{-1}) or vermicompost (1 t ha^{-1}).

Rasool *et al.* (2007) reported that the addition of both FYM and $N_{120}P_{30}K_{30}$ increased the organic carbon by 44 and 37 %, respectively in rice. The total porosity of soil increased with the application of both FYM and $N_{120}P_{30}K_{30}$ from that in control plots. In 0–15 cm soil layer, the total porosity increased by 25% with FYM from that in control plots. The average water holding capacity (WHC) was 16 and 11% higher with FYM and $N_{120}P_{30}K_{30}$ application from that in control plots.

Choudhary *et al.* (2008) reported that the application of various organic manures in wheat resulted in reduction of bulk density of the soil over initial value. In general, bulk density was quite lower in FYM supplied plots and higher in berseem (*Trifolium alexandrinum* L.) green manure plots. There was a significant improvement in soil physical properties like soil moisture content after harvest of each crop, soil water retention and plant available water capacity (PAWC), saturated hydraulic conductivity at various crop growth stages when FYM was applied @ 10 t ha^{-1} to wheat followed by berseem green manuring + FYM, mushroom spent compost + FYM, mushroom spent compost and berseem green manuring, respectively. Increase in fertility levels from 50 to 150% of recommended NPK supplied to wheat crop resulted in decline in bulk density of the soil in each crop, A significant improvement in soil moisture content at harvest of both wheat and rice; soil water retention at different suction values as well as PAWC during experimentation was observed with increase in fertilizer levels.

Ramesh *et al.* (2008) conducted an experiment on effect of organic manures on productivity, soil fertility and economics of soybean (*Glycine max*) - durum wheat (*Titicum durum*) cropping system under organic farming in Vertisols. They reported that the soil organic carbon, and available N, P, K status were significantly improved in organic manure treatments compared to chemical fertilizers.

Pandey *et al.* (2009) reported that addition of organic manure (FYM) with fertilizer levels significantly improved the organic carbon content, N, P and K status after harvest of wheat as compare to chemical fertilizer alone.

Rather and Sharma (2009) conducted an experiment on wheat and reported that significant improvement in soil properties and fertility status was found in 100% RDF + vermicompost + zinc + *PSB*. Organic carbon content of soil improved from 3.0 to 4.6 g kg^{-1} soil, bulk density reduced from 1.50 to 1.32 Mg m^{-3}, water holding capacity increased from 20.32 to 23.72%, available N from 197.0 to 219.0 kg ha^{-1}, available P from 13.0 to 19.1 kg ha^{-1}, available K from 113.0 to 130.4 kg ha^{-1} and available Zn from 1.50 to 1.87 mg kg^{-1} soil by the integration of organics with in organics.

Katkar *et al.* (2011) conducted an experiment on long-term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum (*Sorghum bicolor*)–wheat (*Triticum aestivum*) system in Vertisol. They reported that the significantly highest increase in soil organic carbon and total nitrogen were recorded with 100% NPK + FYM @10 t ha^{-1}. The availability of N, P, K, S were significantly increased with the integrated application of organic manure (FYM @ 10 t ha^{-1}) and mineral fertilizer (100% NPK) over control and other fertilizer treatments after 20 years of experimentation.

Thakur *et al.* (2011) conducted an experiment on impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of Vertisol. They reported that the joint use of FYM with 100% NPK substantially improved the organic carbon status by 3.9 g kg^{-1}, as well as available N, P and S by 126.8, 25.5 and 28.5 kg ha^{-1} in soil over its initial values, thereby indicating significant contribution towards sustaining the soil health.

Devi *et al.* (2011) conducted an experiment and reported that available NPK status of soil after the harvest of wheat were found to be maximum with the application of 100% RDF + vermicompost @ 1 t ha^{-1} + *PSB* and 75% RDF + vermicompost @ 1 t ha^{-1} + *PSB* and the lowest from control.

Abbasi and Tahir (2012) reported that the application of urea with FYM and PM decreased soil bulk density (4-11%), increased organic carbon (10-22%), total N (9-25%), available P (13-26%) and available K (13-23%) compared to the control.

Sepehya *et al.* (2012) reported that 100% NPK (50% NPK+50% N through FYM) to wheat was the best practice than rest of the treatments for improving the soil properties. The highest values of pH, organic carbon, CEC, available N, P and K were recorded under 100% NPK (50% NPK+50% N through FYM) was applied.

Bahadur *et al.* (2013) conducted an experiment on rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system in reclaimed sodic soil and reported that the improvement in soil properties (pH, EC, OC) and soil fertility status (NPK and Zn) was recorded when chemical fertilizers were integrated with organic manures.

Bairwa *et al.* (2013) conducted an experiment on pearl millet-wheat cropping system and reported that the application of organic materials, FYM resulted in highest available N (220.5 kg ha^{-1}), P (21.0 kg ha^{-1}) and K (333.8 kg ha^{-1}) in soil.

Hemalatha and Chellamuthu (2013) reported that the cation exchange capacity of the soil has increased significantly in the treatment receiving 100 per cent NPK+FYM. The organic carbon contents of the soil have increased significantly in all the treatments that received NPK at different levels. The highest value of 6.2 g kg^{-1} was recorded in the treatment receiving NPK+FYM @ 10 t ha^{-1} which was 55 per cent higher than control and also 107 per cent higher than the initial status. Available N, P and K status increased due to 100 percent NPK+FYM application and recorded 195, 26.7, 639 kg ha^{-1} respectively.

Meena and Meena (2013) conducted an experiment on wheat and reported that the available N, P and K status in soil after harvest of the crop increased with nitrogen and poultry manure application.

Sharma *et al.* (2013) reported that the conjunctive use of inorganic fertilizers and organic manure along with biofertilizers and micronutrients gave highest available N, P, K, S and Zn in soil as compared to other treatment combinations in wheat.

Shukla *et al.* (2013) conducted an experiment on effect of vermicompost and microbial inoculants on soil health, growth and yield of wheat and reported that maximum carbon content was recorded in treatment inoculated with *Azotobacter* + PSB + AM fungi along with vermicompost. The nitrogen content was also increased in the soil due to inoculation of *Azotobacter* and *Azospirillum.*

Singh *et al.* (2013) conducted a field experiment on wheat and reported that the highest organic carbon content in soil was recorded with vermicompost 9 t ha^{-1} + FYM 20 t ha^{-1} which was found at par with 25% NPK + vermicompost 6 t ha^{-1} + FYM 20 t/ha.

Parewa *et al.* (2014) conducted an experiment on effect of fertilizer levels, FYM and bio-inoculants on soil properties in inceptisol. They reported that the application of different treatments did not affect the pH and EC while bulk density was decreased, however, water holding capacity, organic carbon, CEC and available N, P and K significantly improved after harvest of wheat.

Bhatt *et al.* (2017) carried out an experiment at Pantnagar and revealed that combined application of inorganic fertilizer and FYM resulted in a positive influx of nutrients by increasing soil pH, electrical conductivity, cation exchange capacity, organic carbon content, available nitrogen, available phosphorus and available potassium in both the surface and sub-surface layer of soil as compared to control after harvest of wheat.

Meena *et al.* (2018) conducted an experiment and revealed that soil pH and bulk density decreased by 20.73% and 20.12%, while soil organic carbon and porosity increased by 49.0% and 32.7% in the treatments where farmyard manure (FYM) was applied either alone, or in combination with inorganic fertilizer as compared to control after harvest of wheat.

2.5 EFFECT ON BIOLOGICAL PROPERTIES OF SOIL

Khaddar and Yadav (2006) conducted an experiment and reported that the application of biofertilizers significantly showed higher bacterial population and fungal population over control in wheat crop.

Majumdar *et al.* (2008) conducted an experiment on organic amendment influenced soil organic pools and crop productivity in nineteen years old rice –wheat agro-ecosystem and reported that the application of NPK and FYM amended soil have higher microbial biomass in wheat.

Menaria and Tenguria (2008) reported that the enumeration of micro-organism (bacteria, fungi and actinomycetes) observed with the application of different IPNM treatments. The best results were observed with 25% NPK + FYM treatment.

Ramesh *et al.* (2008) conducted an experiment on effect of organic manures on productivity, soil fertility and economics of soybean (*Glycine max*) - durum wheat (*Triticum durum*) cropping system under organic farming in Vertisols. They reported that enzyme activity of soil (dehydrogenase and phosphatase activity) was significantly improved in organic manure treatments compared to chemical fertilizers.

Behera (2009) conducted an experiment on organic manuring for soil biological health and productivity of a wheat-soybean cropping system in the Vertisols of central India. He reported that dehydrogenase activity was increased significantly with applications of manures.

Verma and Mathur (2009) reported that the activity of dehydrogenase enzyme was strongly affected by long-term fertilizer use. Maximum activity was noticed in 100% NPK + 10 FYM t ha^{-1} treatment followed by treatment receiving FYM alone (which were at par with each other).

Chauhan *et al.* (2011) reported that organically treated plots have the maximum microbial population counts and microbial biomass carbon which is followed by the inorganically treated plots and control. Organic plots exhibited a significant variation in bacterial population in both the soil depths with the inorganically treated plots and control. The application of organic fertilizers increased the organic carbon content of the soil and thereby increasing the microbial counts and microbial biomass carbon. The use of inorganic fertilizers resulted in low organic carbon content, microbial counts and microbial biomass carbon of the soil, although it increased the soil's nitrogen, phosphorus and potassium level which could be explained by the rates of fertilizers being applied. From the study it has been concluded that the soil under organic agricultural system presents higher microbial activity and microbial biomass carbon than the conventional or inorganic agricultural system.

Katkar *et al.* (2011) conducted an experiment on long-term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum (*Sorghum bicolor*)–wheat (*Triticum aestivum*) system in Vertisol. They reported that soil dehydrogenase activity significantly increased with the integrated application of organic manure (FYM @ 10 t ha^{-1}) and mineral fertilizer (100% NPK) over control and other fertilizer treatments after 20 years of experimentation. Meena *et al*. (2012) also reported that the highest value of dehydrogenase activity (DHA) was found with the application of NPK + FYM with or without ID.

Das and Dakhar (2012) reported that the fungal population was greatest in the vermicompost plot for two crop cycles, whereas bacterial population was greatest in vermicompost in the first crop cycle and FYM for the second crop cycle.

Bahadur *et al.* (2013) reported that the highest microbial population and bacterial population (94.0×10^5 g^{-1} soil) was recorded with application of NPK Zn based on soil test + FYM @ 5 t ha^{-1} + PSB + BGA.

Ingle *et al.* (2014) conducted an experiment on soil biological properties as influenced by long-term manuring and fertilization under sorghum (*Sorghum bicolor*)-wheat (*Triticum aestivum*) sequence in Vertisols. They reported that the application of 100% RDF + FYM @ 10 tonnes ha^{-1} significantly influenced the dehydrogenase activity (55.01 micro g $TPF^{-1}g^{-1}$24 hr) of soil.

Parewa *et al.* (2014) conducted an experiment on effect of fertilizer levels, FYM and bio-inoculants on soil properties in inceptisol of Varanasi, Uttar Pradesh, India. They reported that the dehydrogenase, phosphatase enzyme activity, soil microbial biomass carbon (SMBC) and microbial population of soil after the harvest of wheat were improved significantly due to the integration of inorganic fertilizers with FYM and bioinoculants.

Shah *et al.* (2014) reported that application of manure increased dehydrogenase activity, which is an index of microbial activity of soil. The enzymatic activities NP, NK and NPK treated soil were significantly lower than that of control. Application of FYM in soil enhanced soil dehydrogenase activity from 9.7 and 11.4 ug TPF produced g^{-1} h^{-1} in control to 34.4 and 40.4 ug TPF produced g^{-1} h^{-1} in FYM treatment after maize and wheat. Crop respectively.

2.6 ECONOMICS

Goyal (2002) carried out an experiment and reported that maximum net returns of cropping sequence of ₹ 47011 was obtained at 100% NPK + 10 t FYM ha^{-1} followed by 75% NPK + 10 t FYM ha^{-1} (₹ 45589) and 100% NPK alone (₹ 45657).

Singh *et al.* (2008d) conducted a field experiment during 2003-04 and 2004-05 at Jodhpur. The results showed that integrated use of FYM @ 7.5 t ha^{-1} + 50% RDF (50 kg N + 13.5 kg P ha^{-1}) + biofertilizers (*Azotobacter* + PSB) in wheat – based cropping sequence recorded significantly highest grain yield, net returns and B: C ratio of crop over control.

Kushare *et al.* (2009) reported that interaction effect showed that application of 60:30 kg N:P ha^{-1} (75% RDF) coupled with combined inoculation registered significantly higher grain yield (30.96 q ha^{-1}) of wheat with higher net profit, B:C ratio than those with 80:40 kg N:P/ha (100% RDF) (30 q ha^{-1}) without biofertilizer inoculation.

Rather and Sharma (2009) conducted an experiment on effect of integrated nutrient management (INM) on yield and economics of wheat. They reported that the integration of FYM/vermicompost and Zn and PSB with 100% recommended NPK gave higher net income/ha (₹ 32294) and B: C ratio (2.00) compared to the 50% recommended NPK.

Devi *et al.* (2011) reported that the net returns and benefit: cost ratio increased with supplementation of recommended dose of fertilizer with vermicompost and phosphate solubilizing bacteria. Highest net return (₹ 57227 ha^{-1}) and benefit cost ratio (2.73) was obtained with application of 75% RDF+ vermicompost @1 t ha^{-1}+ PSB than fertilizer alone. The additional cost of organic manures and bio-fertilizer was compensated by the additional yield of wheat.

Singh *et al.* (2013) conducted an experiment on integrated nutrient management in rice and wheat crop in rice-wheat cropping system in lowlands. Application of 100% NPK + 5 t FYM ha^{-1} recorded the highest monetary efficiency (₹ 86.06 ha^{-1} day^{-1}) and net return (₹ 42060 ha^{-1}), system productivity (26.5 kg grain ha^{-1} day^{-1}) and stability yield index (0.99), however benefit: cost ratio being highest (1.36) with 75% NPK + 5t FYM ha^{-1}.

Verma *et al.* (2014) conducted an experiment on effect of integrated soil fertility management practices on production and productivity of wheat in alluvial soils of central plain zone of Uttar Pradesh. They reported that the maximum gross income (₹ 87443) and net income (₹ 37000) were also recorded in RDF + vermicompost 5.0 t ha^{-1} + *Azotobactor* and PSB as seed treatment and sprayed at 1^{st} and 2^{nd} irrigation.

Borse *et al.* (2019) conducted an experiment at Navsari and found that the maximum net returns (₹ 51569 and ₹ 51468) and BCR (2.28 and 2.29) were recorded FYM @ 10 t ha^{-1} and 120% RDF treatments, respectively.

3. MATERIALS AND METHODS

A field experiment entitled **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** was conducted for two consecutive years during *rabi* season of the year 2015-2016 and 2016-2017. The details of experimental techniques, material used and criteria adopted for treatment evaluation during the course of investigation are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted at Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur during *rabi* season of 2015-2016 and 2016-2017. The site was situated at 24^{o}.35' N latitude, 73^{o}.42' E longitude and an altitude of 582.2 m above mean sea level. The region falls under agro-climatic zone IVA (Sub-Humid Southern Plain and Aravalli Hills) of Rajasthan.

3.2 CLIMATE AND WEATHER CONDITIONS

The climate of the region is tropical characterized by mild winter and summer associated with high humidity particularly during July-September. The mean annual rainfall of the region ranges between 580-630 mm, most of which contributed by South-West monsoon from July to September. In summers maximum temperature goes up to 44°C. May and June are the hottest months. Winters are generally rainless and minimum temperature during December and January falls as low as 1°C.

The meteorological observations recorded at Agronomy farm observatory, Rajasthan College of Agriculture, Udaipur during cropping periods are presented in Table and Fig. 3.1a and.3.1b. The wheat crop experienced maximum and minimum temperature ranged between 23.7 to 36.6 °C and 4.0 to 20.1 ^{o}C during *rabi* 2015-16, respectively. The corresponding temperature fluctuations during second year (2016-17) of experimentation were 20.9 to 38.1 °C and 5.6 to 19.7 °C, respectively. Mean weekly maximum and minimum relative humidity ranged between 39.7 to 83.6 per cent and 16.9 to 35.0 per cent, respectively during 2015-16 and the corresponding values in the year 2016-17 were 46.0 to 92.1 per cent and 10.8 to 47.0 per cent. Total rainfall received during the crop season was 0.0 mm during 2015-16 and 12.4 mm in 2016-17, respectively.

Table 3.1(a) Mean weekly weather parameters during crop growing season (2015-16)

SMW	Period	Max. Temp. (ºC)	Min. Temp. (ºC)	Max. RH (%)	Min. RH (%)	Sunshine (hrs.)	Rainfall (mm)
46	12 to18 Nov	25.8	10.1	79.4	29.3	7.7	0.0
47	19 to25 Nov	27.9	9.0	73.4	25.0	8.9	0.0
48	26 to 2 Dec	28.3	11.7	64.6	34.6	5.9	0.0
49	3 to 9 Dec	29.3	8.6	70.3	35.0	8.4	0.0
50	10 to 16 Dec	25.0	6.8	69.6	33.6	8.0	0.0
51	17 to 23 Dec	23.9	4.0	77.3	23.6	7.4	0.0
52	24 to 31Dec	27.5	6.9	78.4	18.6	7.4	0.0
1	1 to 7 Jan	28.7	9.7	83.6	26.0	7.2	0.0
2	8 to 14 Jan	27.3	8.3	83.0	25.3	7.5	0.0
3	15 to 21 Jan	23.7	8.0	83.1	35.0	4.9	0.0
4	22 to 28 Jan	25.9	6.0	80.1	22.1	8.9	0.0
5	29 to 4 Feb	27.7	10.0	72.0	27.7	8.2	0.0
6	5 to11 Feb	26.6	7.3	78.0	19.6	9.1	0.0
7	12 to 18 Feb	26.0	12.2	68.1	27.3	8.2	0.0
8	19 to 25 Feb	30.5	11.9	66.9	18.4	7.6	0.0
9	26 to 4 Mar	31.6	11.6	67.5	21.0	8.9	0.0
10	5 to 11 Mar	31.7	14.1	67.6	28.7	8.5	0.0
11	12 to 18 Mar	30.9	15.1	70.0	32.1	6.7	0.0
12	19 to 25 Mar	34.1	15.7	51.7	17.9	8.4	0.0
13	26 to 1 Apr	35.9	17.9	52.6	19.7	6.1	0.0
14	2 to 8 Apr	36.6	20.1	50.6	18.9	6.3	0.0
15	9 to 15 Apr	36.3	19.5	39.7	16.9	7.7	0.0

Table 3.1(b) Mean weekly weather parameters during crop growing season (2016-17)

SMW	Period	Max. Temp (ºC)	Min. Temp. (ºC)	Max. RH. (%)	Min. RH (%)	Sunshine (hrs.)	Rainfall (mm)
46	12 to18 Nov	29.5	15.4	74.4	36.7	6.2	11.0
47	19 to25 Nov	29.7	12.1	76.3	27.0	8.7	0.0
48	26 to 2 Dec	30.5	10.7	82.4	23.1	9.0	0.0
49	3 to 9 Dec	30.3	10.6	80.4	24.7	9.0	0.0
50	10 to 16 Dec	27.7	8.9	88.7	27.6	8.6	0.0
51	17 to 23 Dec	28.3	10.4	90.1	32.4	8.7	0.0
52	24 to 31Dec	27.5	9.8	89.4	29.1	8.6	0.0
1	1 to 7 Jan	28.0	9.3	85.8	24.6	8.6	0.0
2	8 to 14 Jan	26.2	8.3	92.1	37.9	7.9	0.0
3	15 to 21 Jan	20.9	5.6	89.6	38.8	5.7	0.0
4	22 to 28 Jan	21.8	7.1	80.7	43.1	6.4	0.0
5	29 to 4 Feb	25.9	10.4	91.6	47.0	5.3	1.4
6	5 to11 Feb	26.9	8.6	91.5	36.0	8.6	0.0
7	12 to 18 Feb	25.1	7.2	84.1	28.7	8.4	0.0
8	19 to 25 Feb	27.4	10.9	88.0	34.1	8.0	0.0
9	26 to 4 Mar	30.0	11.1	71.4	26.0	8.7	0.0
10	5 to 11 Mar	31.4	12.7	71.1	26.0	9.1	0.0
11	12 to 18 Mar	29.1	12.2	73.1	23.7	7.7	0.0
12	19 to 25 Mar	29.2	10.1	63.0	16.8	8.6	0.0
13	26 to 1 Apr	34.1	15.1	73.6	17.4	8.8	0.0
14	2 to 8 Apr	38.1	18.6	46.4	10.8	9.5	0.0
15	9 to 15 Apr	36.4	19.7	46.0	17.2	9.2	0.0

Source: Agromet observatory, Instructional Farm, Department of Agronomy, RCA, Udaipur.

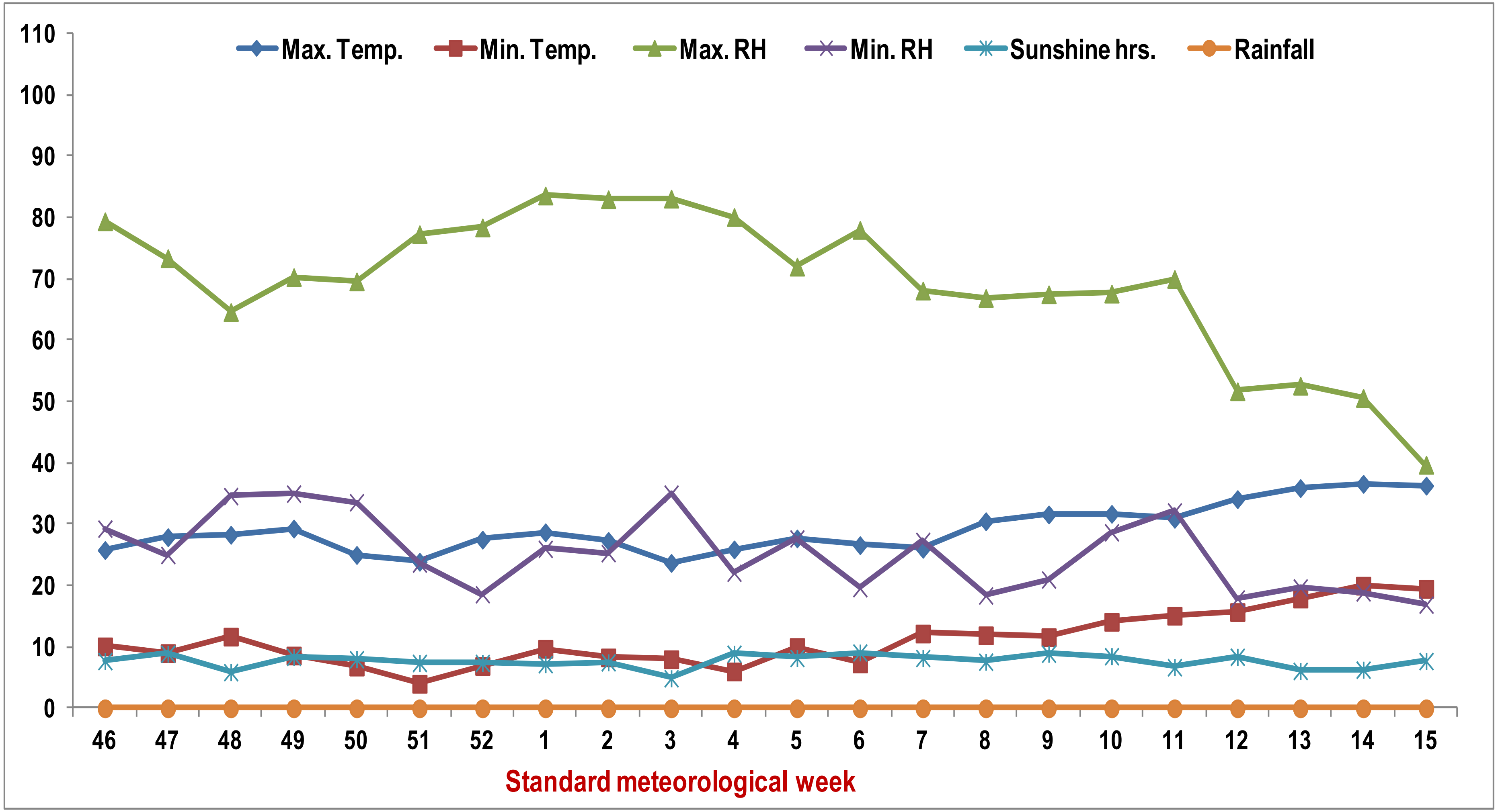


Fig 3.1(a) Mean weekly weather parameters during crop growing season (2015-16)

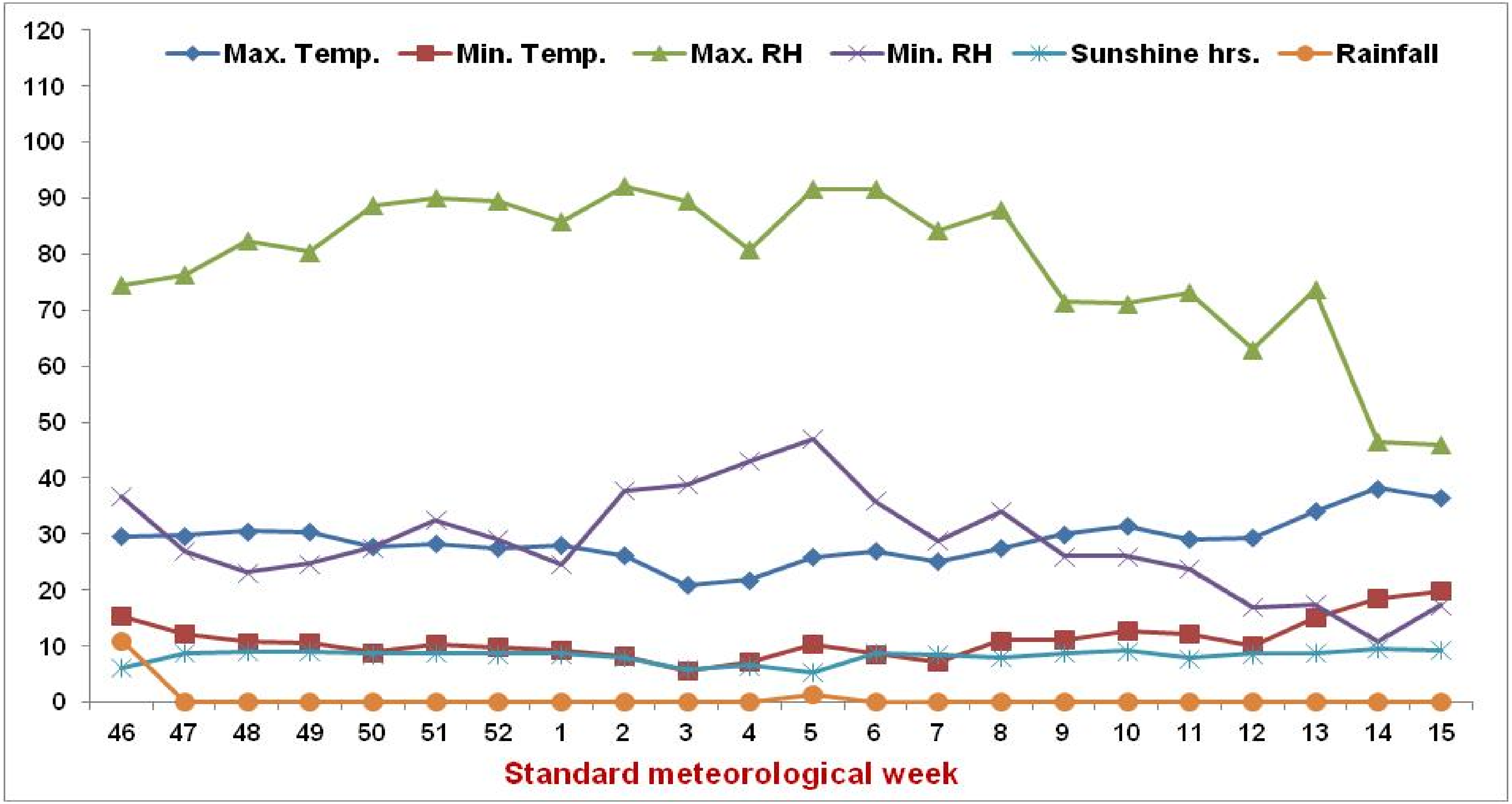


Fig. 3.1(b) Mean weekly weather parameters during crop growing season (2016-17)

3.3 PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF SOIL

To ascertain mechanical and physico-chemical characteristics of the soil, surface soil (0-15 cm depth) samples were collected from different spots of the experimental field in both the years. Representative composite samples obtained from samples of each year, were subjected to physico-chemical and biological analysis separately using standard methods. From the result of soil analysis (Table 3.2), it can be inferred that the soil of the experimental field was alkaline in reaction, medium in available nitrogen and phosphorus and high in available potassium.

Table 3.2 Physico-chemical and biological properties of experimental soil (0-15 cm)

Properties	2015-16	2016-17
A. Mechanical analysis		
Sand (%)	38.67	38.75
Silt (%)	26.16	26.28
Clay (%)	34.47	34.35
Textural class	Clay loam	Clay loam
B. Physical analysis		
Bulk density (Mg m^{-3})	1.45	1.41
Particle density (Mg m^{-3})	2.42	2.48
Porosity (%)	41.60	44.53
Water holding capacity (%)	35.20	38.42
C. Chemical analysis		
pH (1:2, soil : water)	8.10	8.18
EC (dSm^{-1}) (1:2, soil: water)	0.46	0.48
Organic carbon (%)	0.61	0.64
Available nitrogen (kg N ha^{-1})	315.61	320.52
Available phosphorus (kg P_2O_5 ha^{-1})	21.30	24.67
Available potassium (kg K_2O ha^{-1})	305.20	310.15
D. Biological analysis		
Dehydrogenase activity ($\mu gTPFg^{-1}soil$)	3.80	3.91
Bacterial Population (CFU g^{-1})	27.42×10^5	28.05×10^5
Fungi population (CFU g^{-1})	26.53×10^4	27.20×10^4

3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

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

Table 3.3 Cropping history of the experimental field

Year	*Kharif*	*Rabi*
2013-2014	Maize	Wheat
2014-2015	Maize	Wheat
2015-2016	Maize	Wheat*
2016-2017	Maize	Wheat*

* Experimental crop

3.5 EXPERIMENTAL DETAILS

The field experiment on wheat in *rabi* seasons 2015-16 and 2016-17 was laid out in a factorial randomized block design with three replications comprising 3 levels of fertility (50, 75 and 100% RDF), 4 levels of organic sources (5 t FYM, 10 t FYM, 2.5 t vermicompost and 5.0 t vermicompost ha^{-1}) and 2 bio-inoculants (Without inoculation and PSB + *Azotobacter*). The treatments and their symbols used are given in table 3.4.

Table 3.4 Details of treatment with their symbols

Treatments	Symbols
Fertility levels	
i 50 % RDF	F_1
ii 75 % RDF	F_2
iii 100 % RDF	F_3
Organic sources	
i 5 t FYM ha^{-1}	O_1
ii 10 t FYM ha^{-1}	O_2
iii 2.5 t vermicompost ha^{-1}	O_3
iv 5 t vermicompost ha^{-1}	O_4
Bio-inoculants	
i Without inoculation	B_1
ii Dual inoculation (*Azotobacter* + PSB)	B_2

3.6 EXPERIMENTAL DESIGN AND LAYOUT

The experiment on wheat in *rabi* season was laid out in a factorial randomized block design with three replications. The treatments were randomly allotted to different plots by using random number table (Fisher and Yates 1963). The plan of layout of experiments for wheat is shown in fig. 3.2 and other details of experiment are given below:

1.	Season	Rabi 2015-16 to 2016-17
2.	Crop	Wheat
3.	Variety	Raj-4037
4.	Seed rate	100 kg ha^{-1}
5.	Experimental design	Randomized Block Design (Factorial)
6.	Replications	3
7.	Treatment combinations	24
8.	Total no. of plots	24 x 3 = 72
9.	Gross plot size	2.70 m x 4.5 m = 12.15 m^2
	Net plot size	2.25 m x 4.0 m = 9.0 m^2
10.	Sources of nutrients	
	N	Urea + DAP
	P	DAP
	K	MOP
11.	Crop geometry	22.5 cm x 10 cm
12.	Location	Agronomy farm
13.	Irrigation	As per recommendation

3.7 TREATMENT APPLICATION

(a) Fertilizers

The application of 120 kg N, 60 kg P_2O_5 and 40 kg K_2O are recommended dose of fertilizer for wheat crop. Fertilizer application 50, 75 and 100 per cent of RDF was made as per treatment allocation.

(b) Organic sources

Organic sources (FYM and Vermicompost) were thoroughly mixed and applied as per allocation of treatments in plots before 15 days prior to wheat sowing. The application of organic sources as per the treatments applied in both the year. Nutrients composition of organic sources applied in the experiment is given in table 3.5 and 3.6.

Table 3.5 Chemical composition of organic sources (2015-16)

Manures	N (%)	P (%)	K (%)
FYM	0.53	0.26	0.58
Vermicompost	1.12	0.54	0.32

Table 3.6 Chemical composition of organic sources (2016-17)

Manures	N (%)	P (%)	K (%)
FYM	0.55	0.27	0.60
Vermicompost	1.15	0.55	0.34

(c) Biofertilizers

(i) **PSB:** The seeds were inoculated with microphosculture *i.e. Bacillus megatherium* var. *phosphaticum* @ 5 g kg^{-1} seed as per standard procedure 2-3 hours before sowing and sown in ear marked plots.

(ii) ***Azotobacter:*** The seeds were thoroughly mixed with biofertilizer slurry in such a way that all the seeds were uniformly coated with *Azotobacter* inoculums as per the treatments using 500 g ha^{-1} and then allowed to dry in the shade before the sowing of crop. Than after sown in ear marked plots.

3.8 DETAILS OF CROP RAISING

The schedule of different pre and post sowing operations carried out during the crop season is given in Table 3.7 and the chronological record of crop raising are described as under:

Table 3.7 Schedule of field operations during crop growth periods

S. No.	Operation	Date	
		2015-16	2016-17
1.	Field preparation	01.11.2015	02.11.2016
2.	Layout, bunding and application of organic manures as per treatment	04.11.2015	04.11.2016
3.	Fertilizer application and sowing	20.11.2015	21.11.2016
4.	Irrigation		
	(a) Post sowing	20.11.2015	21.11.2016
	(b) First irrigation + urea topdressing	13.12.2015	15.12.2016
	(c) Second irrigation + urea topdressing	04.01.2016	05.01.2017
	(d) Third irrigation	31.01.2016	31.01.2017
	(e) Fourth irrigation	28.02.2016	27.2.2017
	(f) Fifth irrigation	16.03.2016	18.03.2017
5.	Herbicide spray (2, 4- D easter)	21.12.2015	26.12.2016
6.	Harvesting	10.04.2016	15.04.2017
7.	Threshing and winnowing	25.04.2016	28.04.2017

3.8.1 Field Preparation

The experimental field was prepared after pre-sowing irrigation by ploughing with tractor drawn disc plough followed by cross harrowing and planking to bring the soil in to good tilth without disturbing the four corner points and then bunds were prepared at the original place of each plot.

3.8.2 Seed and Sowing

Before sowing, wheat seed were first inoculated with biofertilizers as per treatment. A seed rate of 100 kg ha^{-1} was used. The seed were sown in opened furrows manually at a depth of 5 cm in rows spaced at 22.5 cm apart. Fertilizers were placed beneath the seed, after placing the seed in furrows it was covered with soil for uniform germination and to protect from bird damage.

3.8.3 Irrigation

The crop was irrigated at critical growth stages viz., crown root initiation (CRI), tillering, late jointing (boot), milking stage and dough during both the years of experimentation. The respective dates of irrigation to crops are presented in table 3.6.

3.8.4 Weed Management

In order to reduce the weed competition, one spray of 2,4-D @ 0.5 kg *a.i* ha^{-1} (Knock Weed 36 % EC) was applied at 30 DAS as post-emergence spray through knapsack sprayer fitted with flat fan nozzle using 600 liters of water ha^{-1}.

3.8.5 Harvesting

The crop was harvested from a net plot of 2.25 m x 4.0 m (9.0 m^2) separately and produce was tied in bundles and tagged. These bundles were left on the threshing floor for sun drying.

3.8.6 Threshing and Winnowing

After thorough drying, the harvested produce of the each plot was weighed with the help of balance to record biological yield $plot^{-1}$. The threshing was done with a power operated thresher. The produce thus obtained from each plot was winnowed, cleaned and weighed on physical balance and recorded as the grain yield $plot^{-1}$ (kg). The stover yield was computed by deducting the weight of seed yield from total biological yield.

3.9 TREATMENT EVALUATION

The treatment effects were evaluated in terms of following parameters of soil and the crop.

3.9.1 Plant Studies

3.9.1.1 Grain yield

The grain yield of each net plot was recorded in kg $plot^{-1}$after cleaning the threshed produce and was converted as q ha^{-1}.

3.9.1.2 Stover yield

Stover yield was obtained by subtracting the grain yield (q ha^{-1}) from biological yield (q ha^{-1}).

3.9.1.3 Biological yield

The harvested material from net area of each plot was thoroughly sun dried. After drying, the produce of individual net plot was weighed with the help of a spring balance and recorded in q ha^{-1}.

3.9.1.4 Harvest Index (HI)

The harvest index was calculated by using following formula and expressed as percentage as suggested by Donald and Hablin (1976).

$$\text{H.I. (\%)} = \frac{\text{Grain yield (q ha}^{-1})}{\text{Biological yield (q ha}^{-1})} \times 100$$

3.9.1.5 Nutrient content

The wheat plant samples were collected at the time of threshing from each plot and oven dried. The dried samples were finely ground and used for determination of N, P, K, Fe, Mn, Zn and Cu content as per method furnished in Table 3.8.

Table 3.8 Methods followed for plant analysis

Character under analysis	Method used	Reference
1. Nitrogen Digestion with H_2SO_4-H_2O_2	Nessler's reagent, spectrophotometrically	Snell and Snell (1959)
2. Phosphorus Digestion with di-acid HNO_3 : $HClO_4$ (10 : 4)	Vanadomolybdate phosphoric acid yellow colour method	Jackson (1967)
3. Potassium	Flame photometer method	Jackson (1967)
4. Zn, Mn, Cu and Fe content	Analysis of suitable aliquot of digested material (II) with the help of atomic absorption spectrophotometer	Lindsay and Norvell (1978)

3.9.1.6 Nutrient uptake

The uptake of nitrogen, phosphorus, potassium, iron, manganese, zinc and copper after harvest in grain and stover was estimated by using the following relationship:

$$\text{N/P/K uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in grain/stover (\%)} \times \text{Grain/stover yield (kg ha}^{-1}\text{)}}{100}$$

The uptake of iron, manganese, zinc and copper by grain and stover was computed from iron/manganese/zinc/copper content in grain and stover using the following relationship:

$$\text{Fe/Mn/Zn/Cu uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient content in grain/stover (\%)} \times \text{Grain/stover yield (kg ha}^{-1}\text{)}}{1000}$$

3.9.1.7 Total uptake

The total uptake of N, P, K, Fe, Mn, Zn and Cu at harvest was computed by summing up the nutrient uptake by grain and straw.

3.9.1.8 Protein content in grain

Protein content in grain was calculated by multiplying nitrogen content (%) in grain by the factor 6.25 (A.O.A.C., 1960).

3.9.2 Soil parameters

The undisturbed soil samples from each plot were drawn with the help of auger from 0 to 15 cm depth at the time of harvest of wheat. These soil samples were processed and stored in polyethylene bags till they were analyzed for various parameters. The parameters of soil *i.e.* pH, EC, organic carbon, available N, P, K, Fe, Mn, Zn, Cu, dehydrogenase activity, bacteria and fungi population were determined by using standard methods of analysis as given in table 3.9.

Table 3.9 Methods followed for soil analysis

Character under analysis	Method used	Reference
Soil Analysis		
1. Soil texture	By international pipette method	Piper (1950)
2. Bulk density	Core sampler method	Piper (1950)
3. Particle density	Pycnometer method	Black (1965)
4. Porosity	Computed from BD and PD	Black (1965)
5. Water Holding Capacity		Veihmeyer and Hendrickson (1931)
6. pH	pH meter	Richards (1954)
7. EC	Conductivity solubridge	Richards (1954)
8. Organic carbon (%)	Wet digestion with $K_2Cr_2O_7$ and H_2SO_4	Walkley and Black (1934)
9. Available nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
10. Available phosphorus	Olsen's method	Olsen *et al.* (1954)
11. Available potassium	Extraction with 1 N ammonium acetate at pH 7.0 and estimated by Flame photometer	Richards (1954)
12. Available Fe, Mn, Zn and Cu	Analysis of suitable aliquot of DTPA extract with the help of atomic absorption spectrophotometer	Lindsay and Norvell (1978)
13. Dehydrogenase activity $\mu g TPF g^{-1} soil$	Colorimtric determination of TPF	Casida *et al*. (1964)
14. Bacterial and Fungal population CFU g^{-1}	Standard serial dilution and plate count method	Scmidt and Colwell(1967)

3.10 ECONOMICS OF THE TREATMENTS

3.10.1 Net Returns

The economics of different treatments was worked out in terms of net returns (₹ ha^{-1}) and B: C ratio, on the basis of prevailing market prices for inputs and output. The cost of cultivation for each treatment was subtracted from the gross returns worked out for the respective treatment to arrive at net returns for each treatment.

3.10.2 Benefit Cost Ratio

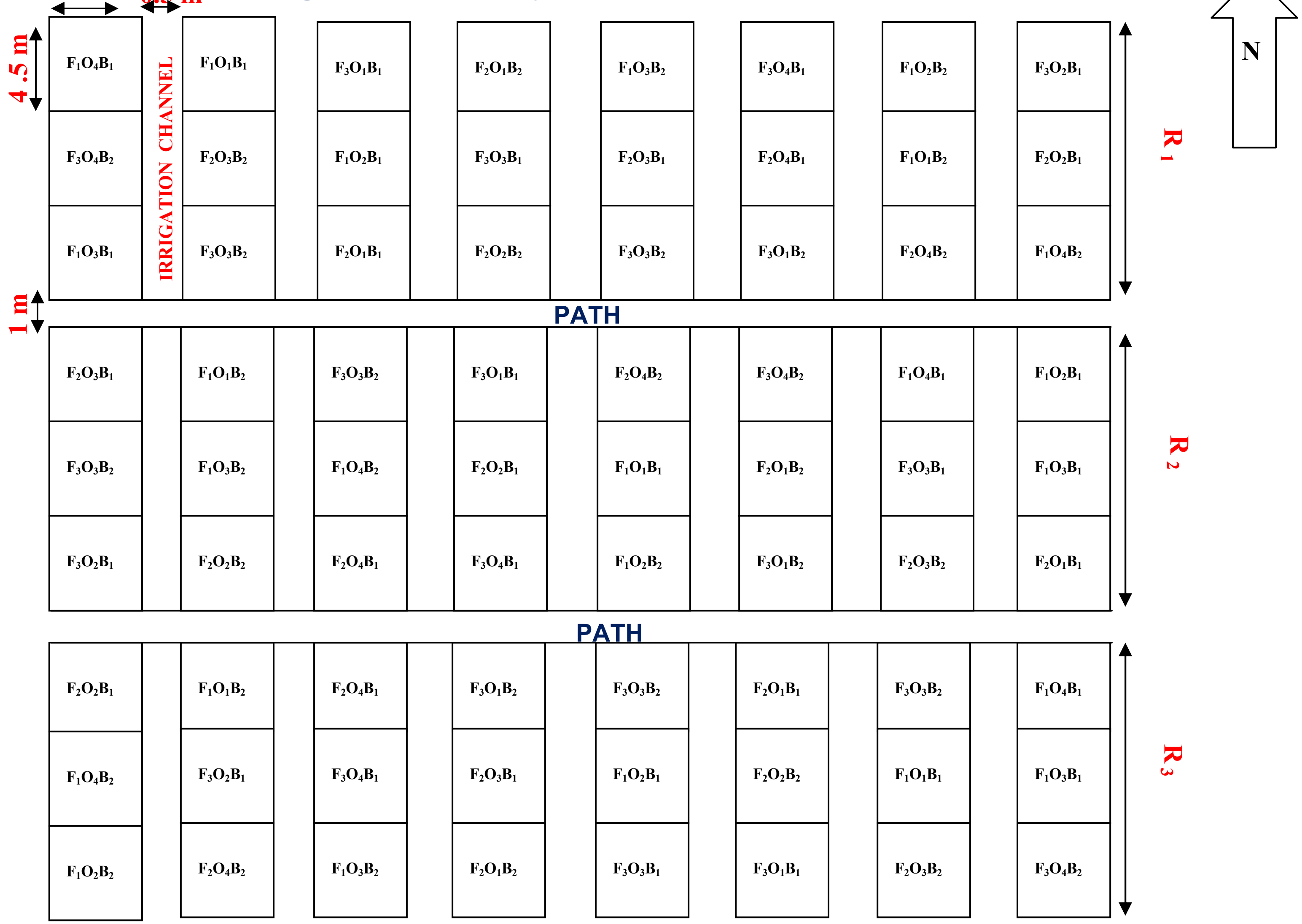
Treatment wise benefit cost ratio was calculated to ascertain economic viability of the treatment using following formula:

$$\text{B/C ratio} = \frac{\text{Gross returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.11 STATISTICAL ANALYSIS

In order to test the significance of variance in experiments, the data obtained for various treatment effects were statistically analyzed as per procedure described by Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment means wherever, the “F” test was found significant at 5 per cent and 1 per cent level of significance. The analysis of variance for all the data presented and discussed has been given in appendices at the end.

Fig 3.2 : Plan of Layout, 2015-16 and 2016-17



Fertility levels	Organic sources	Bio-inoculants	
F_1 = 50 % RDF	O_1 = 5 t FYM ha^{-1}	B_1 = Without inoculation	Design : Factorial RBD
F_2 = 75 % RDF	O_2 = 10 t FYM ha^{-1}	B_2 = PSB + *Azotobacter*	Gross plot size : 2.7 m x 4.5 m
F_3 = 100 % RDF	O_3 = 2.5 t vermicompost ha^{-1}		Net plot size : 2.25 m x 4 m
	O_4 = 5 t vermicompost ha^{-1}		

4. EXPERIMENTAL RESULTS

Results of the experiment entitled **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** conducted during *rabi* season of 2015-16 and 2016-17 at Agronomy Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur are presented in this chapter. Data pertaining to the effect of treatments on plant and soil parameters were statistically analyzed to test the significance of the results. Analyses of variance of these data have been presented (Appendices I to XXXXI) at the end. Graphical illustrations of important characters are also given for the better understanding of the treatment trends.

4.1 PLANT STUDIES

4.1.1 Yield Attributes and Yield

4.1.1.1 Effective tillers metre^{-1} row length

Effect of fertility levels: It is apparent from the data (Table 4.1 and Fig 4.1) that the number of effective tillers metre^{-1} row length of wheat responded significantly with the application of 75% RDF over 50% RDF and thereafter, increased non significantly with further increase with 100% RDF during both the years and in pooled analysis. The magnitude of increase in mean number of effective tillers metre^{-1} row length due to 75% RDF (105.0) was 14.63 per cent over 50% RDF (91.6).

Effect of organic sources: Wheat crop fertilized with 5 t vermicompost ha^{-1} resulted in significant increase in the number of effective tillers over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but it remained at par with 10 t FYM ha^{-1} during both the years of study as well as on pooled basis (Table 4.1 and Fig 4.1). Application of 5 t vermicompost ha^{-1} significantly increased the mean number of effective tillers plant^{-1} (110.9) by 21.73 and 15.88 per cent over 5 t FYM ha^{-1} (91.1) and 2.5 t vermicompost ha^{-1} (95.7), respectively.

Effect of bio-inoculants: Further examination of data (Table 4.1 and Fig 4.1) revealed that inoculation with biofertilizer significantly affect the effective tillers during both the years and pooled basis. On pooled mean basis dual inoculation of wheat seeds with *Azotobacter* + PSB (104.8) significantly increased the effective tillers by 6.50 per cent over no inoculation (98.4).

4.1.1.2 Number of grains spike^{-1}

Effect of fertility levels: Increasing fertility level up to 75% RDF significantly increase the number of grains spike^{-1} in wheat, beyond this level did not increase it significantly any further during both the years and in pooled analysis (Table 4.1 and Fig 4.2). Application of 75% RDF increased the mean number of grains spike^{-1} (42) by 14.13 per cent over 50% RDF (36.8).

Effect of organic sources: Results presented in Table 4.1 and Fig 4.2 showed that application of 5 t vermicompost ha^{-1} significantly increased the number of grains spike^{-1} of wheat during both the years as well as on pooled basis. Application of 10 t FYM ha^{-1} compared with 5 t vermicompost ha^{-1} did not increase it significantly any further. The per cent improvement in mean number of grains spike^{-1} with the application of 5 t vermicompost ha^{-1} (44.4) were 22.31 and 15.93 per cent over 5 t FYM ha^{-1} (36.3) and 2.5 t vermicompost ha^{-1} (38.3), respectively.

Effect of bio-inoculants: A critical examination of data (Table 4.1 and Fig 4.2) further indicated that inoculation of wheat seeds with *Azotobacter* + PSB increased the number of grains spike^{-1} of wheat significantly over no inoculation during both the years and in pooled analysis. When compared with pooled number of grains spike^{-1} of 39.50 recorded under without inoculation, dual inoculation of wheat seeds with *Azotobacter* + PSB (41.9) increased it significantly by 6.08 per cent.

4.1.1.3 Test weight (g)

Effect of fertility levels: A perusal of data presented in Table 4.1 and Fig 4.3 revealed that increasing levels of fertilizer significantly differed with respect to the test weight of grains over 50 per cent RDF during both the years of experiment and pooled basis. The significantly maximum test weight was found wherein crop was supplied with 75 percent RDF over 50 per cent RDF and statistically at par with 100

Table 4.1 Effect of fertility levels, organic sources and bio-inoculants on yields attributes of wheat

Treatments	Effective tillers m^{-1} row length			No. of grains $spike^{-1}$			Test weight (g)		
	2015-16	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
Fertility levels									
50% RDF	90.9	92.3	91.6	36.2	37.5	36.8	37.1	38.3	37.7
75% RDF	103.7	106.2	105.0	41.5	42.5	42.0	38.7	40.7	39.7
100% RDF	106.8	109.7	108.3	42.7	43.9	43.3	40.6	41.4	41.0
SEm ±	1.6	1.9	1.3	0.6	0.8	0.5	0.5	0.9	0.5
CD (P = 0.05)	4.6	5.5	3.5	1.8	2.3	1.4	1.4	2.5	1.4
Organic sources									
FYM (5 t ha^{-1})	90.3	91.8	91.1	35.9	36.7	36.3	36.6	37.8	37.2
FYM (10 t ha^{-1})	108.3	109.2	108.8	43.3	44.5	43.9	40.6	40.9	40.7
VC (2.5 t ha^{-1})	93.2	98.2	95.7	37.3	39.3	38.3	37.3	39.3	38.3
VC (5 t ha^{-1})	110.0	111.8	110.9	44.0	44.7	44.4	40.8	42.5	41.7
SEm ±	1.9	2.2	1.4	0.7	0.9	0.6	0.6	1.0	0.6
CD (P = 0.05)	5.3	6.3	4.1	2.1	2.6	1.6	1.6	2.9	1.7
Bio-inoculants									
Without inoculation	97.6	99.3	98.4	38.9	40.1	39.5	37.9	38.9	38.4
*Azotobacto*r + PSB	103.4	106.2	104.8	41.3	42.5	41.9	39.8	41.4	40.6
SEm ±	1.3	1.6	1.0	0.5	0.6	0.4	0.4	0.7	0.4
CD (P = 0.05)	3.7	4.5	2.9	1.5	1.8	1.2	1.1	2.1	1.2

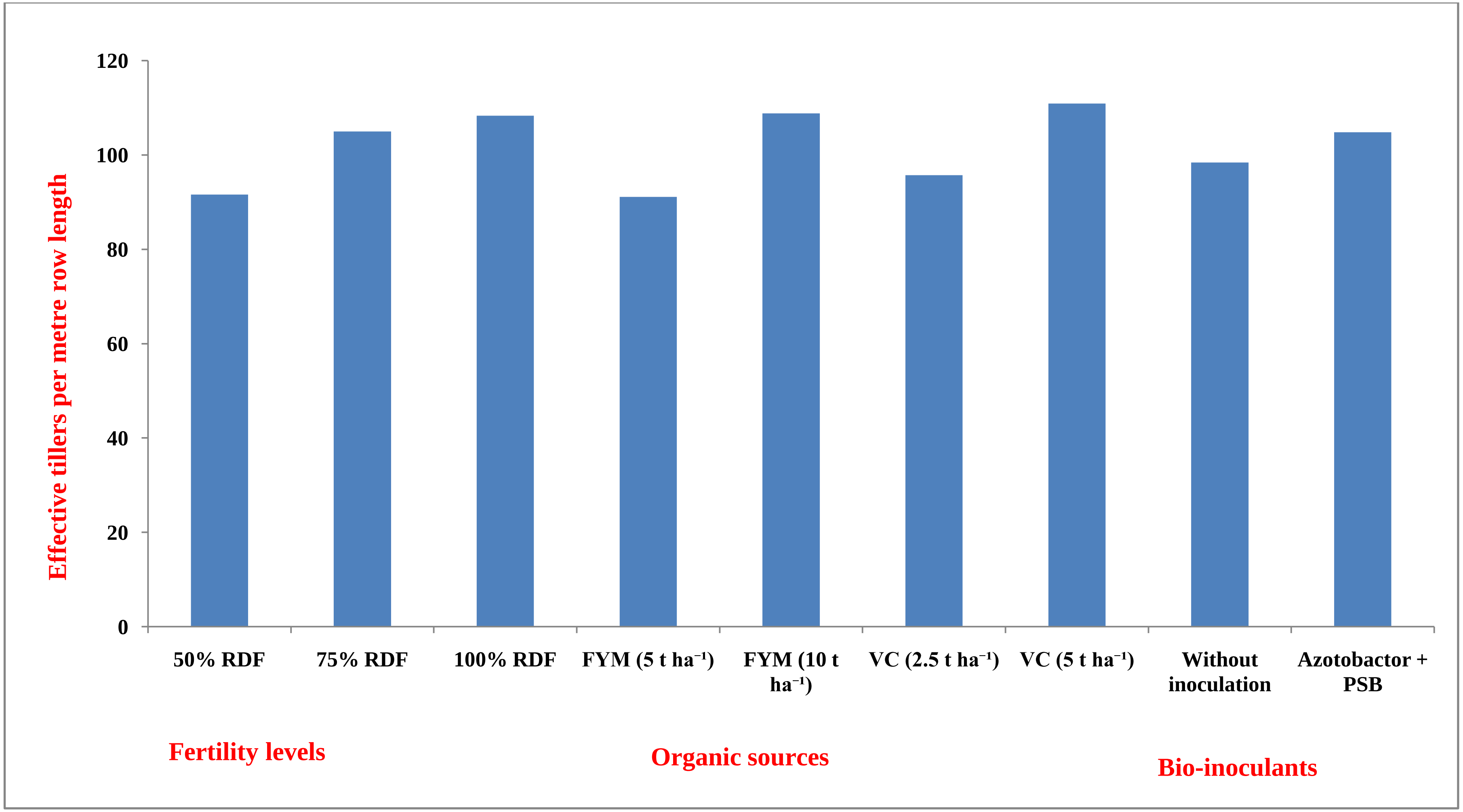


Fig. 4.1 Effect of fertility levels, organic sources and bio-inoculants on effective tillers per metre row length of wheat (Pooled)

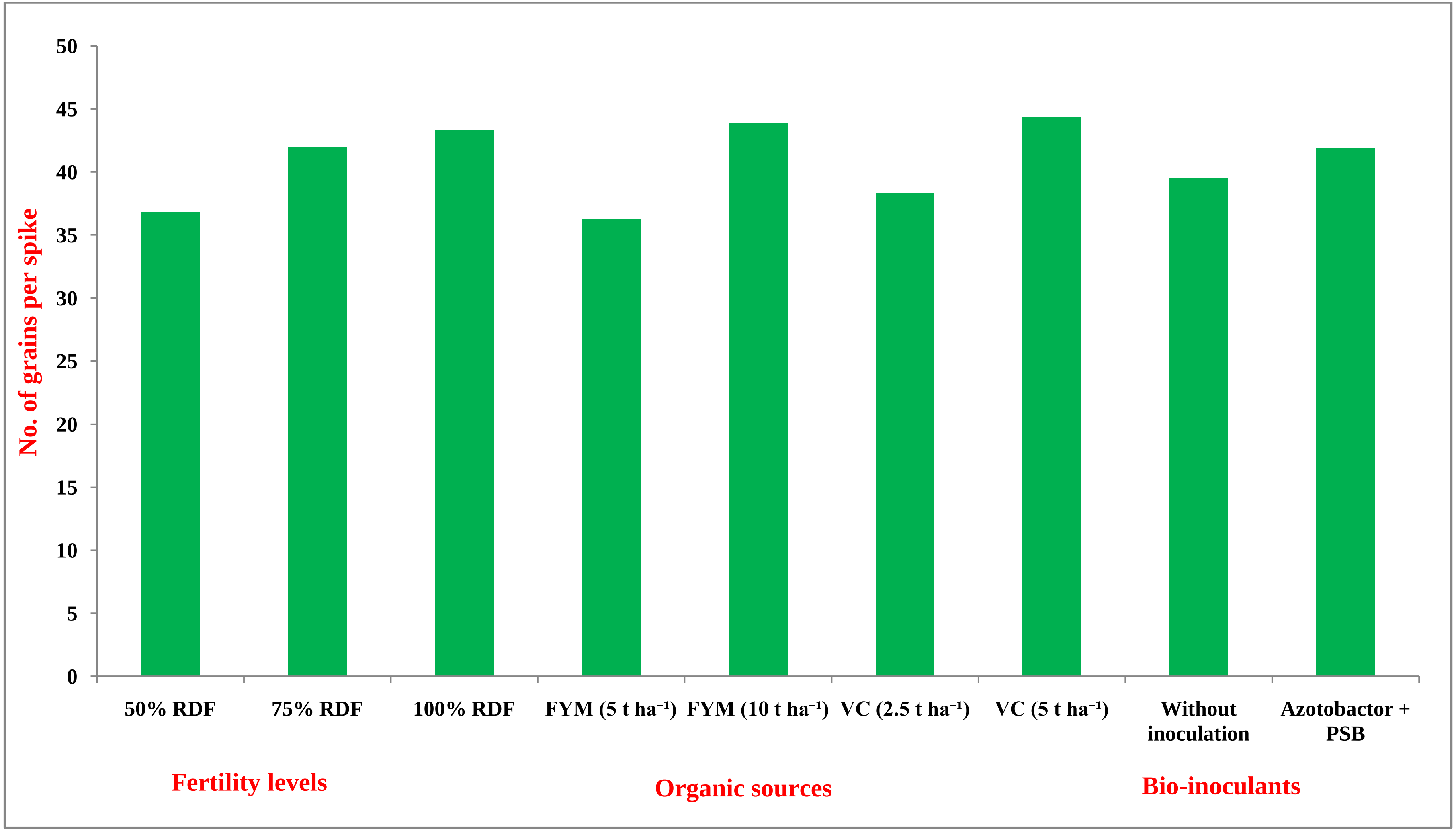


Fig. 4.2 Effect of fertility levels, organic sources and bio-inoculants on number of grains per spike of wheat (Pooled)

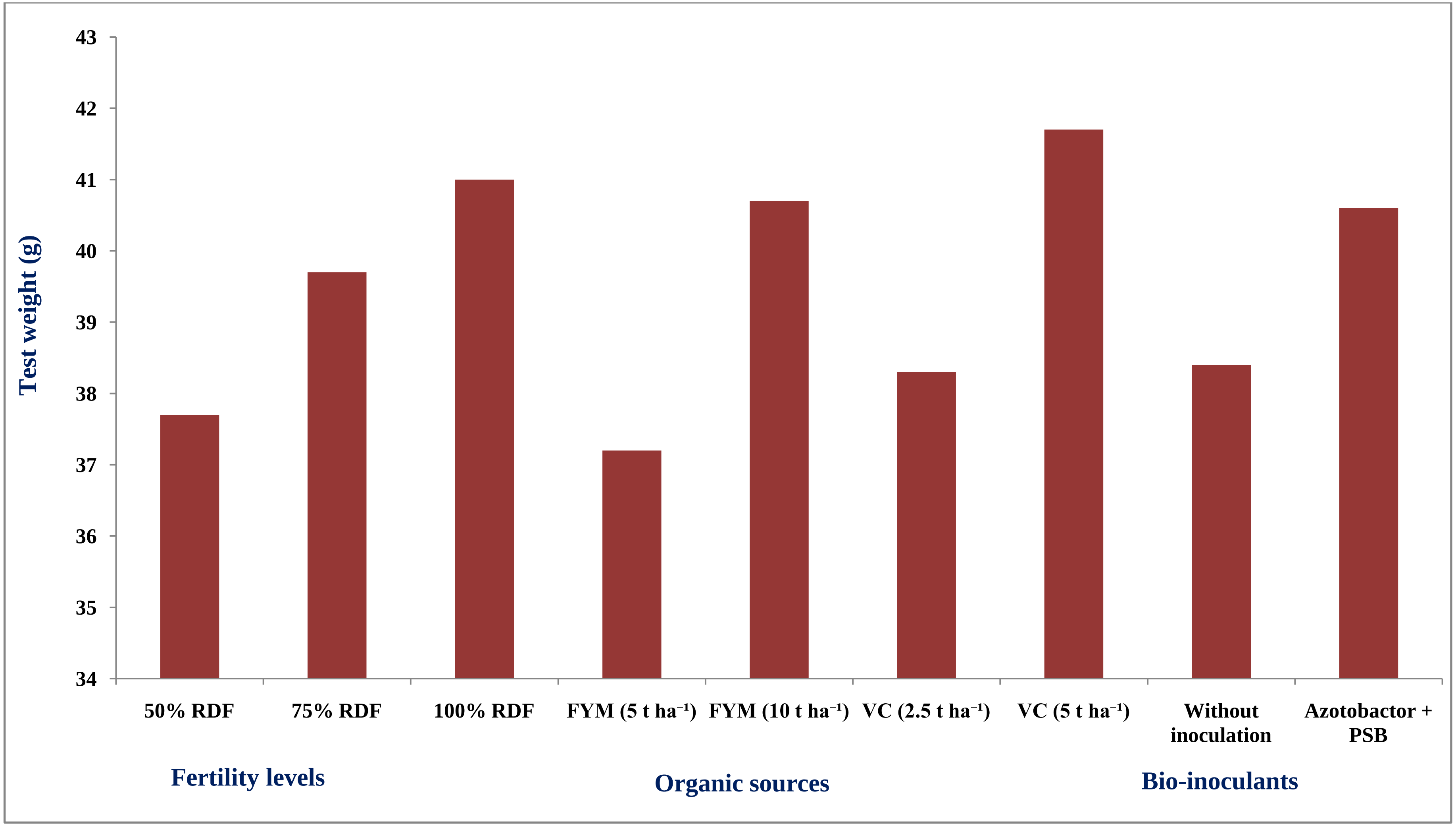


Fig. 4.3 Effect of fertility levels, organic sources and bio-inoculants on test weight of wheat (Pooled)

per cent RDF during both the year and in pooled. On pooled basis, application of 100 and 75 per cent RDF resulted in 5.31 and 3.27 per cent increase in test weight over 50 per cent RDF, respectively.

Effect of organic sources: Data on test weight under the influence of different treatments of organic manures are presented in Table 4.1 and Fig 4.3. Data revealed that the application of different organic manures showed varying results with respect to test weight of grains over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} during both the years and pooled mean basis. The significantly maximum test weight recorded under 5 t vermicompost ha^{-1} superior over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and statistically at par with FYM @ 10 t ha^{-1} during both the years and in pooled mean. Application of vermicompost @ 5 t ha^{-1} resulted in 12.10 and 8.88 per cent increase in test weight over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4.1 and Fig 4.3 showed that test weight of grains was significantly affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum test weight was recorded under combined application of *Azotobacter* + PSB over without inoculation. On pooled basis dual inoculation of wheat seeds with *Azotobacter* + PSB resulted in 5.73 per cent increase in test weight over without inoculation.

4.1.1.4 Grain yield

Effect of fertility levels: An assessment of data presented in Table 4.2 and Fig 4.4 revealed that wheat crop responded significantly to each higher level of fertility up to 75 % RDF (45.6 q ha^{-1}) but it remained at par with 100 % RDF (47.6 q ha^{-1}) in terms of grain yield during both the years of investigations as well as in pooled analysis and resulting in 14.57 per cent increase over 50 % RDF (39.8 q ha^{-1}).

Effect of organic sources: It is also inferred from the data presented in Table 4.2 and Fig 4.4 that wheat crop responded significantly with application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but it remained at par with 10 t FYM ha^{-1} in terms of grain yield during both the years of investigations as well as in pooled analysis. Increase in grain yield recorded by 5 t vermicompost ha^{-1} was found to be quantitatively marginal and statistically non-significant with 10 t FYM ha^{-1}. Thus, application of 5 t vermicompost ha^{-1} increased the mean grain yield (48.9 q ha^{-1}) significantly by 23.48 and 17.55 per cent over 5 t FYM ha^{-1} (39.6 q ha^{-1}) and 2.5 t vermicompost ha^{-1} (41.6 q ha^{-1}), respectively.

Effect of bio-inoculants: The experimental findings presented in Table 4.2 and Fig 4.4 further showed that inoculation of seeds with *Azotobacter* + PSB significantly increased the grain yield of wheat during both the years as well as on pooled analysis. The per cent increase in grain yield with the application of *Azotobacter* + PSB (45.9 q ha^{-1}) was 7.24 per cent over without inoculation (42.8 q ha^{-1}).

Interaction effect of fertility levels and organic manures: Data (Table 4.3) showed that the interaction between fertility levels and organic manures was found to be significant on grain yield of wheat. The significantly maximum grain yield (50.09 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum grain yield (32.71 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.1.5 Straw yield

Effect of fertility levels: A perusal of data (Table 4.2 and Fig 4.4) revealed that increasing level of fertilizer up to 50 % RDF resulted in significant increase in straw yield during both the years of study and in pooled analysis. When compared with mean straw yield of 79.7 q ha^{-1} recorded under 50 % RDF, application of 75 and 100% RDF increased it by 14.30 and 17.69 per cent, respectively.

Effect of organic sources: Data also revealed that significant improvement in straw yield was observed with 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and at par with 10 t FYM ha^{-1} during both the years and in pooled analysis (Table 4.2 and Fig 4.4). Further application of 5 t vermicompost ha^{-1} resulted in non-significant increase in straw yield with 10 t FYM ha^{-1}. Application of 5 t vermicompost ha^{-1} (94.5 q ha^{-1}) increased the mean straw yield significantly by 14.27 and 12.90 per cent over 5 t FYM ha^{-1} (82.7 q ha^{-1}) and 2.5 t vermicompost ha^{-1} (83.7), respectively.

Effect of bio-inoculants: The data further showed that inoculation of seeds with *Azotobacter* + PSB significantly increased the straw yield of wheat during both the years as well as on pooled analysis (Table 4.2 and Fig 4.4). On pooled mean basis dual inoculation of wheat seeds with *Azotobacter* + PSB (90.0 q ha^{-1}) significantly increased the straw yield by 4.17 per cent over without inoculation (86.4 q ha^{-1}).

Table 4.2 Effect of fertility levels, organic sources and bio-inoculants on yields and harvest index of wheat

Treatments	Grain Yield (q ha^{-1})			Straw Yield (q ha^{-1})			Biological Yield (q ha^{-1})			Harvest Index (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels												
50% RDF	39.5	40.1	39.8	79.5	80.0	79.7	119.0	120.1	119.6	33.04	33.63	33.33
75% RDF	45.1	46.2	45.6	89.9	92.3	91.1	135.0	138.5	136.7	33.52	33.42	33.47
100% RDF	47.0	48.3	47.6	92.7	94.8	93.8	139.7	143.0	141.4	33.85	34.24	34.05
SEm ±	0.7	0.9	0.6	1.1	1.3	0.9	1.5	1.7	1.1	0.42	0.54	0.34
CD (P = 0.05)	2.1	2.5	1.6	3.2	3.8	2.5	4.1	4.8	3.1	NS	NS	NS
Organic sources												
FYM (5 t ha^{-1})	39.3	39.9	39.6	82.2	83.2	82.7	121.5	123.1	122.3	32.46	32.67	32.57
FYM (10 t ha^{-1})	47.1	47.5	47.3	91.2	92.5	91.9	138.3	140.0	139.2	34.17	34.09	34.13
VC (2.5 t ha^{-1})	40.5	42.7	41.6	83.4	83.9	83.7	124.0	126.6	125.3	32.88	33.79	33.33
VC (5 t ha^{-1})	48.6	49.3	48.9	92.5	96.5	94.5	141.1	145.9	143.5	34.37	34.52	34.45
SEm ±	0.8	1.0	0.7	1.3	1.6	1.0	1.7	1.9	1.3	0.48	0.62	0.39
CD (P = 0.05)	2.4	2.9	1.8	3.7	4.4	2.9	4.8	5.5	3.6	NS	NS	NS
Bio-inoculants												
Without inoculation	42.4	43.2	42.8	85.6	87.1	86.4	128.1	130.2	129.1	33.12	33.50	33.31
*Azotobacto*r + PSB	45.3	46.6	45.9	89.1	91.0	90.0	134.4	137.5	136.0	33.82	34.03	33.93
SEm ±	0.6	0.7	0.5	0.9	1.1	0.7	1.2	1.4	0.9	0.34	0.44	0.28
CD (P = 0.05)	1.7	2.0	1.3	2.6	3.1	2.0	3.4	3.9	2.5	NS	NS	NS

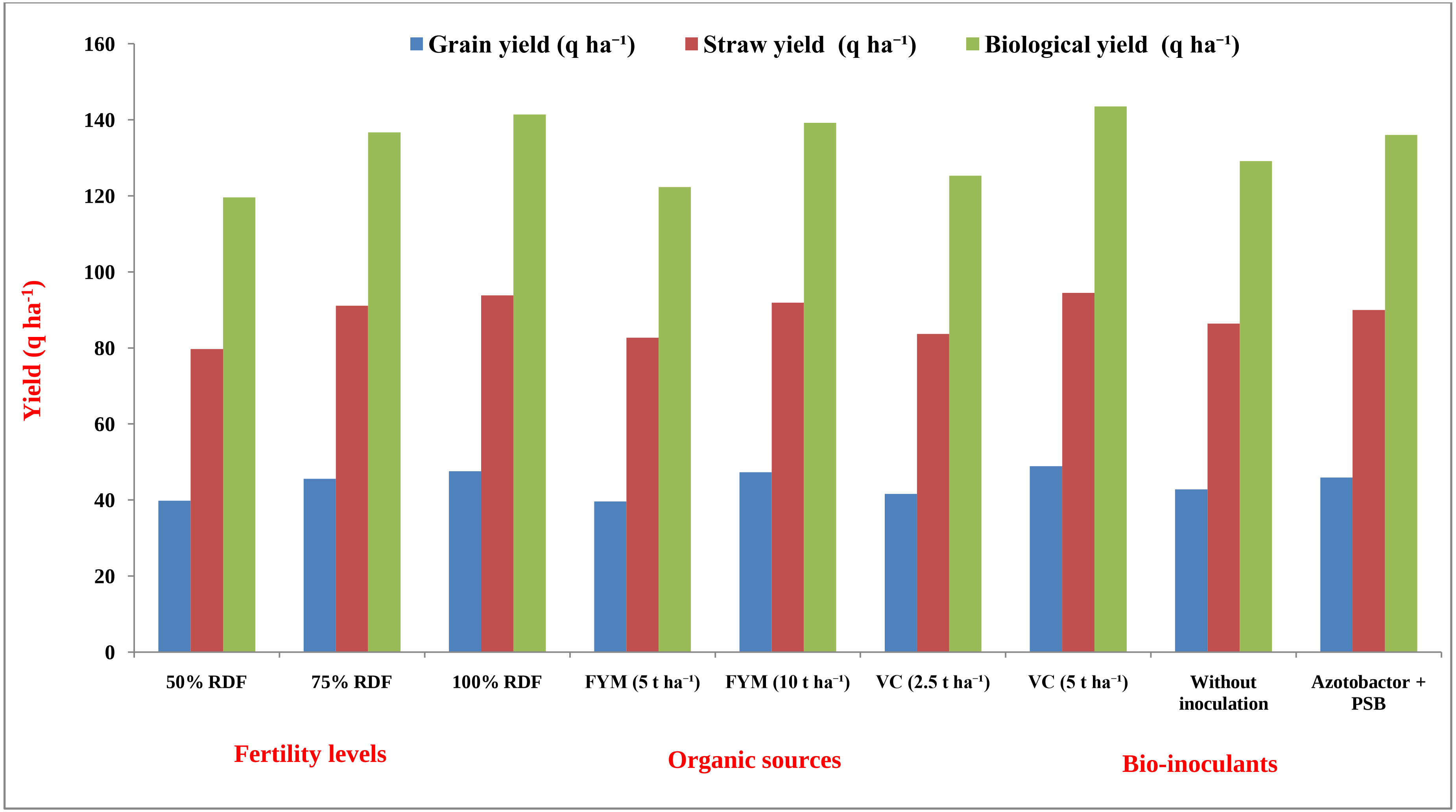


Fig. 4.4 Effect of fertility levels, organic sources and bio-inoculants on yields of wheat (Pooled)

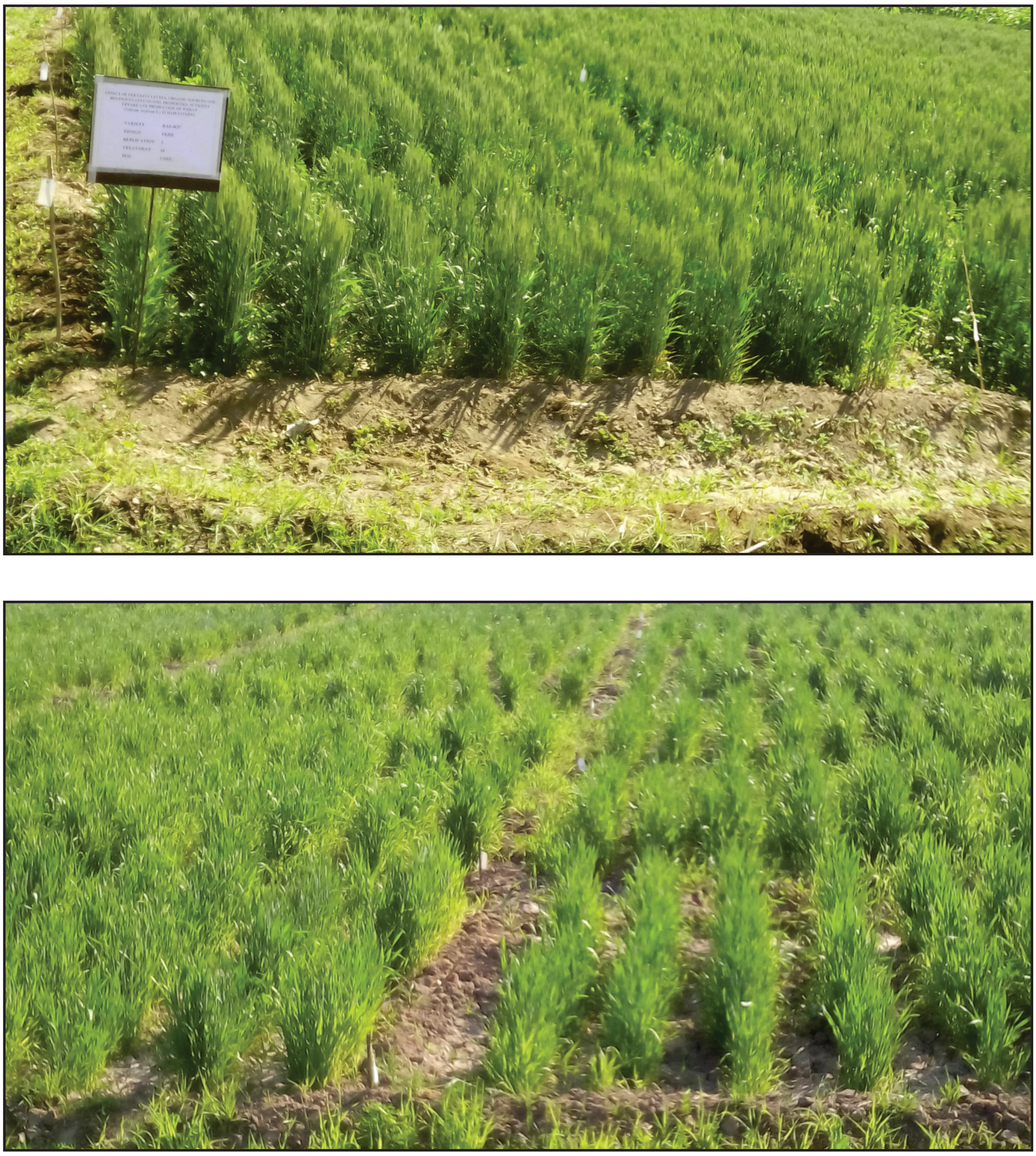


Plate 1: A view of experimental field

Table 4.3 Interaction effect of fertility levels and organic manures on grain yield of wheat

Treatments	Grain Yield (q ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	31.99	39.25	46.55	33.43	43.02	43.29	32.71	41.13	44.92
FYM (10 t ha^{-1})	47.21	45.31	48.77	40.53	51.82	50.11	43.87	48.57	49.44
VC (2.5 t ha^{-1})	36.26	44.90	40.47	37.88	40.66	49.55	37.07	42.78	45.01
VC (5 t ha^{-1})	42.59	50.93	52.14	48.65	49.24	50.08	45.62	50.09	51.11
SEm±	1.17			1.43			0.65		
CD (P=0.05)	3.35			4.07			1.83		

Interaction effect of fertility levels and organic manures: It is clear from the data in Table 4.4 that the interaction between fertility levels and organic manures was found to be significant on straw yield of wheat. The significantly maximum straw yield (98.92 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum straw yield (71.68 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.1.6 Biological yield

Effect of fertility levels: A critical examination of data (Table 4.2 and Fig 4.4) showed that progressive increase in fertility level up to 75% RDF significantly enhanced the biological yield of wheat during both the years of study and in pooled analysis over 50 % RDF but remained at par with 100 % RDF. Application of 75 % RDF (136.7 q ha^{-1}) increased the mean biological yield by 14.30 per cent over 50 % RDF (119.6 q ha^{-1}).

Effect of organic sources: There was significant increase in biological yield of wheat with 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} during both the years and in pooled analysis (Table 4.2 and Fig 4.4). However, application of 5 t vermicompost ha^{-1} found non-significant effect in biological yield with 10 t FYM ha^{-1}. The mean biological yield increased due to application of 5 t vermicompost ha^{-1} (143.5 q ha^{-1}) were 17.33 and 14.53 per cent over 5 t FYM ha^{-1} (122.3 q ha^{-1}) and 2.5 t vermicompost ha^{-1} (125.3 q ha^{-1}), respectively.

Effect of bio-inoculants: The data (Table 4.2 and Fig 4.4) further showed that inoculation of seeds with *Azotobacter* + PSB significantly increased the biological yield of wheat during both the years as well as on pooled analysis. On pooled mean basis dual inoculation of wheat seeds with *Azotobacter* + PSB (136.0 q ha^{-1}) significantly increased the biological yield by 5.34 per cent over without inoculation (129.1 q ha^{-1}).

Interaction effect of fertility levels and organic manures: It is inferred that the combined application of fertility levels and organic manures on biological yield of wheat was found to be significant (Table 4.5). The significantly maximum biological yield (149.0 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum biological yield (104.4 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.1.7 Harvest index

A perusal of data in Table 4.2 showed that the harvest index was not affected significantly due to application of different levels of fertility, organic sources and bio-inoculants.

4.1.2 Nutrient Content, Uptake and Quality

4.1.2.1 Nitrogen content in grain

Effect of fertility levels: An examination of data presented in Table 4.6 revealed that increasing levels of fertilizer significantly influenced the nitrogen content in grain over 50 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum nitrogen content in grain was found when soil was enriched with 75 per cent RDF over 50 per cent RDF and statistically at par with 100 per cent RDF during both the years and in pooled analysis. The magnitude of mean nitrogen content in grain increased by 14.60 and 11.68 per cent due to 100 and 75 per cent RDF over 50 per cent RDF, respectively.

Effect of organic sources: Nitrogen content in grain under the influence of different treatments of organic manures are presented in Table 4.6 revealed that the application of different organic manures differed significantly with respect to nitrogen content in grain during both the years and pooled basis. The significantly maximum nitrogen content in grain was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean nitrogen content in grain significantly by 9.93 and 6.16 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4.6 showed that nitrogen content in grain affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum nitrogen content in grain was found with dual inoculation of *Azotobacter* + PSB which was 6.94 per cent higher over without inoculation.

Table 4.4 Interaction effect of fertility levels and organic manures on straw yield of wheat

Treatments	Straw Yield (q ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	72.04	89.06	85.48	71.32	85.16	93.10	71.68	87.11	89.29
FYM (10 t ha^{-1})	82.04	95.12	96.55	91.09	92.29	94.20	86.57	93.71	95.37
VC (2.5 t ha^{-1})	73.45	76.06	100.83	82.51	93.13	75.93	77.98	84.59	88.38
VC (5 t ha^{-1})	90.29	99.31	88.03	75.18	98.52	115.95	82.74	98.92	101.99
SEm±	1.84			2.19			1.01		
CD (P=0.05)	5.25			6.26			2.85		

Table 4.5 Interaction effect of fertility levels and organic manures on biological yield of wheat

Treatments	Biological Yield (q ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	104.0	128.3	132.0	104.8	128.2	136.4	104.4	128.2	134.2
FYM (10 t ha^{-1})	129.3	140.4	145.3	131.6	144.1	144.3	130.4	142.3	144.8
VC (2.5 t ha^{-1})	109.7	121.0	141.3	120.4	133.8	125.5	115.0	127.4	133.4
VC (5 t ha^{-1})	132.9	150.2	140.2	123.8	147.8	166.0	128.4	149.0	153.1
SEm±	2.37			2.74			1.28		
CD (P=0.05)	6.74			7.82			3.60		

Table 4.6 Effect of fertility levels, organic sources and bio-inoculants on nitrogen and protein content of wheat

Treatments	Nitrogen content (%)						Protein content in grain (%)		
	Grain			Straw					
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels									
50% RDF	1.37	1.38	1.37	0.483	0.492	0.487	8.55	8.61	8.58
75% RDF	1.51	1.55	1.53	0.532	0.546	0.539	9.41	9.66	9.54
100% RDF	1.55	1.58	1.57	0.549	0.560	0.555	9.71	9.89	9.80
SEm ±	0.02	0.03	0.02	0.010	0.008	0.007	0.14	0.16	0.11
CD (P = 0.05)	0.07	0.07	0.05	0.029	0.024	0.018	0.41	0.45	0.30
Organic sources									
FYM (5 t ha^{-1})	1.40	1.43	1.41	0.501	0.511	0.506	8.76	8.91	8.84
FYM (10 t ha^{-1})	1.52	1.53	1.53	0.531	0.541	0.536	9.50	9.58	9.54
VC (2.5 t ha^{-1})	1.44	1.48	1.46	0.509	0.526	0.518	9.01	9.28	9.14
VC (5 t ha^{-1})	1.54	1.56	1.55	0.544	0.552	0.548	9.63	9.78	9.70
SEm ±	0.03	0.03	0.02	0.012	0.010	0.008	0.17	0.18	0.12
CD (P = 0.05)	0.08	0.08	0.06	0.033	0.027	0.021	0.48	0.52	0.35
Bio-inoculants									
Without inoculation	1.42	1.46	1.44	0.501	0.520	0.511	8.88	9.15	9.01
Azotobactor + PSB	1.53	1.54	1.54	0.541	0.545	0.543	9.58	9.63	9.60
SEm ±	0.02	0.02	0.01	0.008	0.007	0.005	0.12	0.13	0.09
CD (P = 0.05)	0.05	0.06	0.04	0.023	0.019	0.015	0.34	0.37	0.25

4.1.2.2 Nitrogen content in straw

Effect of fertility levels: The data presented in Table 4.6 revealed that increasing levels of fertilizer significantly influenced the nitrogen content in straw over 50 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum nitrogen content in straw was found with 75 per cent RDF over 50 per cent RDF and remained statistically at par with 100 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 and 75 per cent RDF resulted in 13.96 and 10.68 per cent increase in nitrogen content in straw over 50 per cent RDF, respectively.

Effect of organic sources: Experimental data given in Table 4.6 showed that the nitrogen content in straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum nitrogen content in straw was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean nitrogen content in straw significantly by 8.30 and 5.79 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.6 revealed that inoculation with biofertilizer significantly affect the nitrogen content in straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean nitrogen content in straw by 6.26 per cent over no inoculation.

4.1.2.3 Protein content in grain

Effect of fertility levels: It is evident from the data presented in Table 4.6 that increasing levels of fertilizer significantly increased the protein content of grains in wheat during both the years and in pooled analysis. Data pooled over two seasons revealed that graded levels of fertilizer increased the protein content of wheat with each higher level significantly up to 75 per cent RDF. Application of fertilizers beyond this level did not increase it significantly any further under the study. When compared with protein content of 8.58 per cent recorded under 50% RDF, application of 75% RDF increased it significantly by 11.19 per cent and 100% RDF by 14.22 per cent.

Effect of organic sources: A perusal of data in Table 4.6 showed that the protein content in grain improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum protein content in grain was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean protein content in grain significantly by 9.73 and 6.16 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: An examination of data presented in Table 4.6 revealed that inoculation with biofertilizer significantly improved the protein content in grain during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean protein content in grain by 6.55 per cent over no inoculation.

4.1.2.4 Phosphorus content in grain

Effect of fertility levels: The data presented in Table 4.7 showed that increasing levels of fertilizer significantly influenced the phosphorus content in grain over 50 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum phosphorus content in grain was found when soil was enriched with 75 per cent RDF over 50 per cent RDF and statistically at par with 100 per cent RDF during both the years and in pooled analysis. The magnitude of mean phosphorus content in grain increased by 12.42 and 11.07 per cent due to 100 and 75 per cent RDF over 50 per cent RDF, respectively.

Effect of organic sources: A perusal of data presented in Table 4.7 revealed that the application of different organic manures differed significantly with respect to phosphorus content in grain during both the years and pooled basis. The significantly maximum phosphorus content in grain was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean phosphorus content in grain significantly by 11.18 and 7.30 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Table 4.7 Effect of fertility levels, organic sources and bio-inoculants on P and K content of wheat

Treatments	Phosphorus content (%)						Potassium content (%)					
	Grain			Straw			Grain			Straw		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels												
50% RDF	0.293	0.303	0.298	0.147	0.151	0.149	0.515	0.522	0.518	1.441	1.462	1.451
75% RDF	0.324	0.337	0.331	0.162	0.169	0.165	0.551	0.560	0.555	1.542	1.568	1.555
100% RDF	0.329	0.341	0.335	0.165	0.171	0.168	0.553	0.563	0.558	1.548	1.572	1.560
SEm ±	0.006	0.005	0.004	0.003	0.003	0.002	0.006	0.006	0.004	0.016	0.017	0.012
CD (P = 0.05)	0.016	0.014	0.011	0.008	0.007	0.005	0.017	0.017	0.012	0.047	0.048	0.033
Organic sources												
FYM (5 t ha^{-1})	0.301	0.307	0.304	0.151	0.154	0.152	0.512	0.519	0.516	1.434	1.453	1.444
FYM (10 t ha^{-1})	0.322	0.333	0.328	0.161	0.167	0.164	0.551	0.562	0.556	1.542	1.573	1.558
VC (2.5 t ha^{-1})	0.306	0.324	0.315	0.153	0.162	0.157	0.530	0.539	0.535	1.485	1.509	1.497
VC (5 t ha^{-1})	0.332	0.344	0.338	0.166	0.172	0.169	0.564	0.574	0.569	1.579	1.602	1.591
SEm ±	0.007	0.006	0.004	0.003	0.003	0.002	0.007	0.007	0.005	0.019	0.019	0.014
CD (P = 0.05)	0.019	0.017	0.012	0.009	0.008	0.006	0.019	0.020	0.014	0.054	0.055	0.038
Bio-inoculants												
Without inoculation	0.304	0.316	0.310	0.152	0.158	0.155	0.524	0.534	0.529	1.466	1.496	1.481
*Azotobacto*r + PSB	0.327	0.338	0.332	0.163	0.169	0.166	0.555	0.562	0.559	1.554	1.572	1.563
SEm ±	0.005	0.004	0.003	0.002	0.002	0.002	0.005	0.005	0.003	0.013	0.014	0.010
CD (P = 0.05)	0.013	0.012	0.009	0.007	0.006	0.004	0.014	0.014	0.010	0.038	0.039	0.027

Effect of bio-inoculants: Further examination of data presented in Table 4.7 showed that phosphorus content in grain significantly affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum phosphorus content in grain was found with dual inoculation of *Azotobacter* + PSB which was 7.10 per cent higher over without inoculation.

4.1.2.5 Phosphorus content in straw

Effect of fertility levels: It is evident from the data presented in Table 4.7 that increasing levels of fertilizer significantly influenced the phosphorus content in straw over 50 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum phosphorus content in straw was found with 75 per cent RDF over 50 per cent RDF and remained statistically at par with 100 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 and 75 per cent RDF resulted in 12.75 and 10.74 per cent increase in phosphorus content in straw over 50 per cent RDF, respectively.

Effect of organic sources: The data given in Table 4.7 showed that the phosphorus content in straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum phosphorus content in straw was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean phosphorus content in straw significantly by 11.19 and 7.64 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data (Table 4.7) further showed that inoculation with biofertilizer significantly affect the phosphorus content in straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean phosphorus content in straw by 7.10 per cent over no inoculation.

4.1.2.6 Potassium content in grain

Effect of fertility levels: An examination of data presented in Table 4.7 showed that potassium content in grain significantly influenced with increasing levels of fertilizer during both the years of experiment and on pooled basis. The significantly maximum potassium content in grain was found with 75 per cent RDF over 50 per cent RDF and remained at par with 100 per cent RDF during both the years and in pooled analysis. The percent increase in mean potassium content in grain due to 100 and 75 per cent RDF were 7.72 and 7.14 per cent over 50 per cent RDF, respectively.

Effect of organic sources: Potassium content in grain was significantly influenced with different organic manures during both the years of experimentation and in pooled analysis (Table 4.7). The maximum potassium content in grain was observed with in 5 t vermicompost ha^{-1} as compared to 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but it remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of 5 t vermicompost ha^{-1} increased the mean potassium content in grain significantly by 10.27 and 6.36 per cent over 5 t FYM ha-1 and 2.5 t vermicompost ha-1, respectively.

Effect of bio-inoculants: A critical examination of data (Table 4.7) further indicated that inoculation of wheat seeds with *Azotobacter* + PSB increased the potassium content in grain significantly over no inoculation during both the years and in pooled analysis. The dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean potassium content in grain by 5.67 per cent over without inoculation.

4.1.2.7 Potassium content in straw

Effect of fertility levels: Increasing levels of fertilizer significantly increased the potassium content in straw over 50 per cent RDF during both the years of experimentation and on pooled basis (Table 4.7). Application of 75 per cent RDF recorded significantly maximum potassium content in straw over 50 per cent RDF but remained at par with 100 per cent RDF during both the years and in pooled analysis. The application of 100 and 75 per cent RDF resulted in 7.51 and 7.17 per cent increase in potassium content in straw over 50 per cent RDF, respectively.

Effect of organic sources: The data presented in Table 4.7 showed that the potassium content in straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum potassium content in straw was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean potassium content in straw significantly by 10.18 and 6.28 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data (Table 4.7) further showed that inoculation with biofertilizer significantly affect the potassium content in straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean potassium content in straw by 5.54 per cent over no inoculation.

4.1.2.8 Iron content in grain

Effect of fertility levels: A critical examination of data presented in Table 4.8 revealed that increasing levels of fertilizer significantly influenced the iron content in grain over 50 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum iron content in grain was found when soil was enriched with 75 per cent RDF over 50 per cent RDF and statistically at par with 100 per cent RDF during both the years and in pooled analysis. The magnitude of mean iron content in grain increased by 5.79 and 4.26 per cent due to 100 and 75 per cent RDF over 50 per cent RDF, respectively.

Effect of organic sources: A perusal of data in Table 4.8 showed that iron content in straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum iron content in straw was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean iron content in straw significantly by 8.88 and 6.42 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4.8 showed that iron content in grain significantly affected due to inoculation of biofertilizer during both the years and in pooled analysis. The significantly maximum iron content in grain was found with dual inoculation of *Azotobacter* + PSB which was 3.29 per cent higher over without inoculation.

4.1.2.9 Iron content in straw

Effect of fertility levels: The data presented in Table 4.8 revealed that increasing levels of fertilizer significantly influenced the iron content in straw over 50 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum iron content in straw was found with 75 per cent RDF over 50 per cent RDF and remained statistically at par with 100 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 and 75 per cent RDF resulted in 5.06 and 3.68 per cent increase in iron content in straw over 50 per cent RDF, respectively.

Effect of organic sources: Further examination of data (Table 4.8) showed that the iron content in straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum iron content in straw was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of 5 t vermicompost ha^{-1} increased the mean iron content in straw significantly by 9.08 and 6.61 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4.8 revealed that inoculation with biofertilizer significantly affect the iron content in straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean iron content in straw by 3.66 per cent over no inoculation.

4.1.2.10 Manganese content in grain

Effect of fertility levels: It is evident from the data presented in Table 4.8 that manganese content in grain significantly influenced with increasing levels of fertilizer during both the years of experiment and on pooled basis. The significantly maximum manganese content in grain was found with 75 per cent RDF over 50 per cent RDF and remained at par with 100 per cent RDF during both the years and in pooled analysis. The percent increase in mean manganese content in grain due to 100 and 75 per cent RDF were 12.79 and 7.85 per cent over 50 per cent RDF, respectively.

Effect of organic sources: Manganese content in grain was significantly influenced with different organic manures during both the years of experimentation and in pooled analysis (Table 4.8). The maximum manganese content in grain was observed with in

Table 4.8 Effect of fertility levels, organic sources and bio-inoculants on Fe and Mn content of wheat

Treatments	Iron content (mg kg^{-1})						Manganese content (mg kg^{-1})					
	Grain			Straw			Grain			Straw		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels												
50% RDF	91.35	93.18	92.27	147.42	149.09	148.25	14.19	14.44	14.31	19.80	20.62	20.21
75% RDF	95.25	97.15	96.20	152.39	155.03	153.71	15.45	15.99	15.72	21.93	22.84	22.38
100% RDF	96.90	98.31	97.61	154.79	156.71	155.75	15.89	16.39	16.14	22.05	23.11	22.58
SEm ±	0.97	0.98	0.69	1.13	1.23	0.83	0.25	0.22	0.17	0.24	0.33	0.20
CD (P = 0.05)	2.76	2.80	1.94	3.21	3.50	2.34	0.72	0.62	0.47	0.67	0.94	0.57
Organic sources												
FYM (5 t ha^{-1})	90.37	92.18	91.28	144.60	147.49	146.04	14.27	14.83	14.55	20.34	21.19	20.77
FYM (10 t ha^{-1})	96.49	98.26	97.37	154.94	156.10	155.52	15.68	15.80	15.74	21.66	22.57	22.11
VC (2.5 t ha^{-1})	92.46	94.31	93.39	147.94	150.90	149.42	14.98	15.50	15.24	21.03	21.80	21.42
VC (5 t ha^{-1})	98.67	100.11	99.39	158.66	159.95	159.30	15.78	16.29	16.03	22.00	23.21	22.60
SEm ±	1.12	1.14	0.80	1.30	1.42	0.96	0.29	0.25	0.19	0.27	0.38	0.23
CD (P = 0.05)	3.19	3.23	2.24	3.70	4.04	2.70	0.83	0.72	0.54	0.77	1.08	0.66
Bio-inoculants												
Without inoculation	92.89	94.74	93.81	148.90	150.76	149.83	14.53	15.28	14.91	20.96	21.78	21.37
*Azotobacto*r + PSB	96.11	97.68	96.90	154.17	156.46	155.32	15.82	15.92	15.87	21.56	22.60	22.08
SEm ±	0.79	0.80	0.56	0.92	1.00	0.68	0.21	0.18	0.14	0.19	0.27	0.17
CD (P = 0.05)	2.25	2.29	1.58	2.62	2.85	1.91	0.59	0.51	0.38	0.55	0.77	0.46

5 t vermicompost ha^{-1} as compared to 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but it remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of 5 t vermicompost ha^{-1} increased the mean manganese content in grain significantly by 10.17 and 5.18 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: A further examination of data (Table 4.8) indicated that inoculation of wheat seeds with *Azotobacter* + PSB increased the manganese content in grain significantly over no inoculation during both the years and in pooled analysis. The dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean manganese content in grain by 6.44 per cent over without inoculation.

4.1.2.11 Manganese content in straw

Effect of fertility levels: The data presented in Table 4.8 revealed that increasing levels of fertilizer significantly influenced the manganese content in straw over 50 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum manganese content in straw was found with 75 per cent RDF over 50 per cent RDF and remained statistically at par with 100 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 and 75 per cent RDF resulted in 11.73 and 10.74 per cent increase in manganese content in straw over 50 per cent RDF, respectively.

Effect of organic sources: Experimental data given in Table 4.8 showed that the manganese content in straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum manganese content in straw was observed with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean manganese content in straw significantly by 8.81 and 5.51 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.8 revealed that inoculation with biofertilizer significantly affect the manganese content in straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean manganese content in straw by 3.32 per cent over no inoculation.

4.1.2.12 Zinc content in grain

Effect of fertility levels: A perusal of data presented in Table 4.9 revealed that zinc content in grain significantly influenced with increasing levels of fertilizer during both the years of experiment and on pooled basis. The significantly maximum zinc content in grain was found with 75 per cent RDF over 50 per cent RDF and remained at par with 100 per cent RDF during both the years and in pooled analysis. The percent increase in mean zinc content in grain due to 100 and 75 per cent RDF were 12.12 and 9.85 per cent over 50 per cent RDF, respectively.

Effect of organic sources: Data in Table 4.9 indicated that application of different organic manures differed significantly with respect to zinc content in grain during both the years and pooled basis. The significantly maximum zinc content in grain was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean zinc content in grain significantly by 10.27 and 5.73 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data (Table 4.9) showed that inoculation of wheat seeds with *Azotobacter* + PSB increased the zinc content in grain significantly over no inoculation during both the years and in pooled analysis. The dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean zinc content in grain by 6.45 per cent over without inoculation.

4.1.2.13 Zinc content in straw

Effect of fertility levels: A critical examination of data presented in Table 4.9 revealed that increasing levels of fertilizer significantly influenced the zinc content in straw over 50 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum zinc content in straw was found with 75 per cent RDF over 50 per cent RDF and remained statistically at par with 100 per cent RDF during both the years of experimentation and in pooled analysis. The percent increase in zinc content in straw due to application of 100 and 75 per cent RDF were 13.18 and 10.57 per cent as compared to 50 per cent RDF, respectively.

Effect of organic sources: A perusal of data given in Table 4.9 showed that the zinc content in straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly

Table 4.9 Effect of fertility levels, organic sources and bio-inoculants on Zn and Cu content of wheat

Treatments	**Zinc content (mg kg^{-1})**						**Copper content (mg kg^{-1})**					
	Grain			**Straw**			**Grain**			**Straw**		
	2015-16	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
Fertility levels												
50% RDF	28.37	28.87	28.62	16.69	16.98	16.84	7.01	7.15	7.08	3.19	3.24	3.21
75% RDF	30.90	31.97	31.44	18.30	18.93	18.62	7.60	7.88	7.74	3.45	3.61	3.53
100% RDF	31.54	32.65	32.09	18.82	19.29	19.06	7.80	8.03	7.92	3.51	3.67	3.59
SEm ±	0.51	0.44	0.34	0.30	0.27	0.20	0.13	0.11	0.08	0.05	0.06	0.04
CD (P = 0.05)	1.45	1.26	0.95	0.85	0.77	0.57	0.36	0.32	0.24	0.15	0.17	0.11
Organic sources												
FYM (5 t ha^{-1})	28.55	29.67	29.11	16.79	17.45	17.12	7.14	7.31	7.22	3.19	3.31	3.25
FYM (10 t ha^{-1})	31.02	31.59	31.31	18.39	18.86	18.63	7.67	7.84	7.75	3.40	3.55	3.47
VC (2.5 t ha^{-1})	29.73	30.99	30.36	17.62	18.17	17.90	7.32	7.63	7.48	3.33	3.45	3.39
VC (5 t ha^{-1})	31.78	32.41	32.10	18.95	19.13	19.04	7.75	7.97	7.86	3.61	3.72	3.66
SEm ±	0.59	0.51	0.39	0.34	0.31	0.23	0.15	0.13	0.10	0.06	0.07	0.05
CD (P = 0.05)	1.67	1.46	1.09	0.98	0.89	0.65	0.42	0.37	0.28	0.17	0.20	0.13
Bio-inoculants												
Without inoculation	28.95	30.57	29.76	17.18	17.95	17.57	7.15	7.53	7.34	3.18	3.41	3.29
*Azotobacto*r + PSB	31.59	31.76	31.68	18.70	18.85	18.78	7.79	7.84	7.82	3.58	3.60	3.59
SEm ±	0.42	0.36	0.28	0.24	0.22	0.16	0.10	0.09	0.07	0.04	0.05	0.03
CD (P = 0.05)	1.18	1.03	0.77	0.69	0.63	0.46	0.29	0.26	0.19	0.12	0.14	0.09

maximum zinc content in straw was observed with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean zinc content in straw significantly by 11.21 and 6.37 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.9 revealed that inoculation with biofertilizer significantly affect the zinc content in straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean zinc content in straw by 6.89 per cent over no inoculation.

4.1.2.14 Copper content in grain

Effect of fertility levels: The data (Table 4.9) revealed that copper content in grain significantly influenced with increasing levels of fertilizer during both the years of experiment and on pooled basis. The significantly maximum copper content in grain was found with 75 per cent RDF over 50 per cent RDF and remained at par with 100 per cent RDF during both the years and in pooled analysis. The percent increase in mean copper content in grain due to 100 and 75 per cent RDF were 11.86 and 9.32 per cent over 50 per cent RDF, respectively.

Effect of organic sources: It is evident from the data in Table 4.9 indicated that application of different organic manures differed significantly with respect to copper content in grain during both the years and pooled basis. The significantly maximum copper content in grain was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean copper content in grain significantly by 8.86 and 5.08 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data (Table 4.9) showed that inoculation of wheat seeds with *Azotobacter* + PSB increased the copper content in grain significantly over no inoculation during both the years and in pooled analysis. The dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean copper content in grain by 6.54 per cent over without inoculation.

4.1.2.15 Copper content in straw

Effect of fertility levels: A perusal of data presented in Table 4.9 revealed that increasing levels of fertilizer significantly influenced the copper content in straw over 50 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum copper content in straw was found with 75 per cent RDF over 50 per cent RDF and remained statistically at par with 100 per cent RDF during both the years of experimentation and in pooled analysis. The percent increase in copper content in straw due to application of 100 and 75 per cent RDF were 11.84 and 9.97 per cent as compared to 50 per cent RDF, respectively.

Effect of organic sources: Examination of data given in Table 4.9 showed that the copper content in straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum copper content in straw was observed with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} and remained at par with 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean copper content in straw significantly by 12.62 and 7.96 per cent over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data (Table 4.9) further revealed that inoculation with biofertilizer significantly affect the copper content in straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean copper content in straw by 9.12 per cent over no inoculation.

4.1.2.16 Nitrogen uptake by grain

Effect of fertility levels: An examination of data presented in Table 4.10 and fig 4.5 revealed that increasing levels of fertilizer significantly influenced the nitrogen uptake by grain during both the years of experiment and on pooled basis. The significantly maximum nitrogen uptake by grain was found when soil was enriched with 100 percent RDF over 50 per cent and 75 per cent RDF during both the years and in pooled analysis. The magnitude of mean nitrogen uptake by grain increased by 35.03 and 6.48 per cent due to 100 RDF over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: Nitrogen uptake by grain under the influence of different treatments of organic manures are presented in Table 4.10 and fig 4.5 revealed that the application of different organic manures differed significantly with respect to

Table 4.10 Effect of fertility levels, organic sources and bio-inoculants on nitrogen uptake by wheat

Treatments	**Nitrogen uptake (kg ha^{-1})**								
	Grain			**Straw**			**Total**		
	2015-16	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
Fertility levels									
50% RDF	54.40	55.78	55.09	38.61	40.08	39.35	93.02	95.85	94.44
75% RDF	68.26	71.45	69.86	48.20	51.07	49.63	116.45	122.53	119.49
100% RDF	72.62	76.15	74.39	51.05	54.36	52.71	123.67	130.52	127.09
SEm ±	1.24	1.85	1.12	1.15	1.24	0.85	2.04	2.71	1.70
CD (P = 0.05)	3.53	5.28	3.13	3.27	3.54	2.38	5.79	7.72	4.76
Organic sources									
FYM (5 t ha^{-1})	55.11	57.63	56.37	41.20	43.37	42.28	96.31	101.00	98.65
FYM (10 t ha^{-1})	71.00	72.53	71.76	48.82	50.87	49.85	119.83	123.40	121.61
VC (2.5 t ha^{-1})	59.12	63.41	61.27	43.35	44.50	43.93	102.48	107.91	105.19
VC (5 t ha^{-1})	75.13	77.61	76.37	50.44	55.28	52.86	125.58	132.90	129.24
SEm ±	1.43	2.14	1.29	1.33	1.43	0.98	2.35	3.13	1.96
CD (P = 0.05)	4.07	6.09	3.62	3.78	4.08	2.75	6.69	8.92	5.50
Bio-inoculants									
Without inoculation	60.87	63.43	62.15	43.54	46.69	45.11	104.40	110.13	107.26
*Azotobacto*r + PSB	69.32	72.15	70.74	48.37	50.32	49.35	117.69	122.47	120.08
SEm ±	1.01	1.51	0.91	0.94	1.01	0.69	1.66	2.21	1.38
CD (P = 0.05)	2.88	4.31	2.56	2.67	2.89	1.94	4.73	6.30	3.89

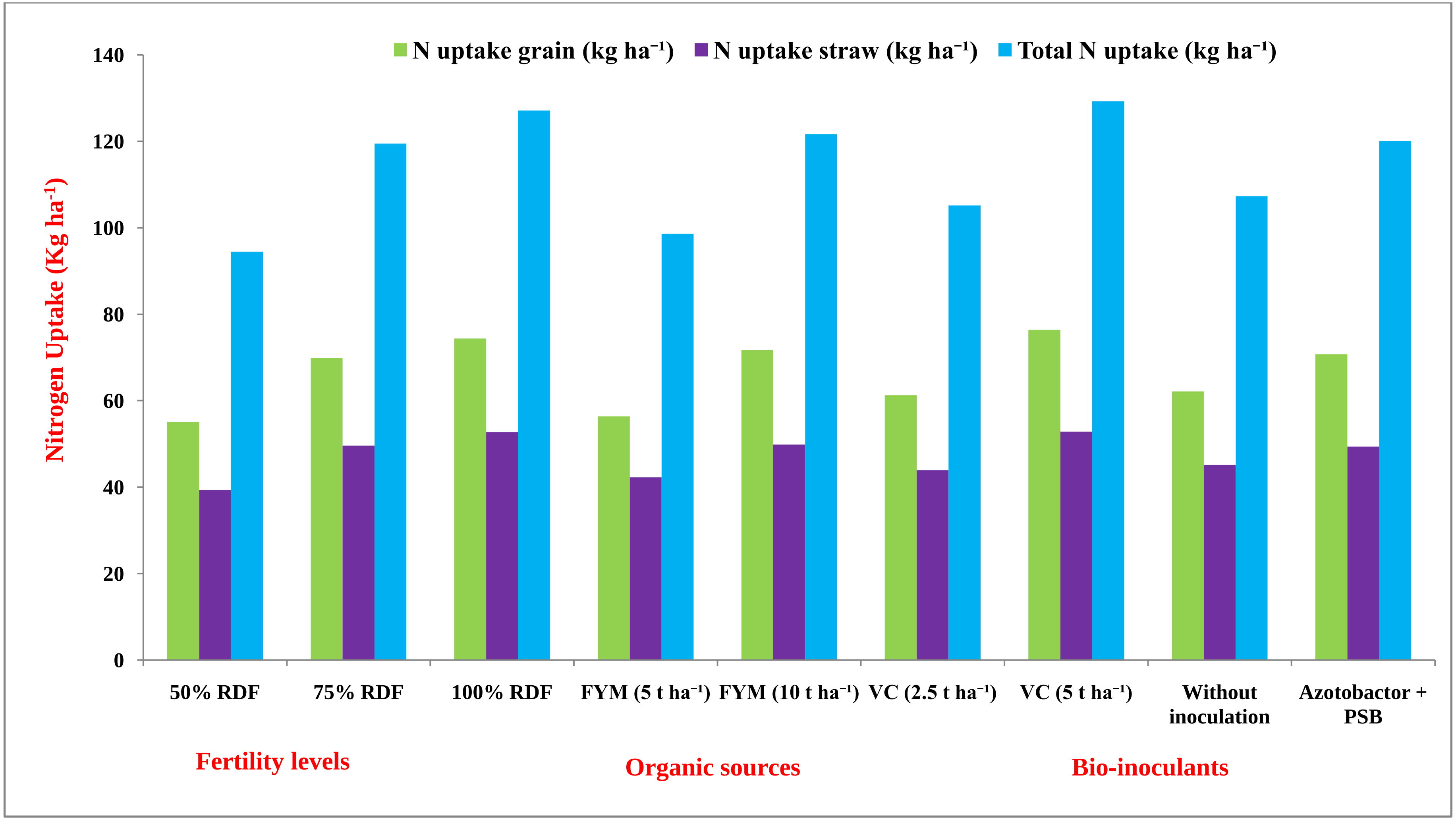


Fig. 4.5 Effect of fertility levels, organic sources and bio-inoculants on nitrogen uptake by wheat (Pooled)

nitrogen uptake by grain during both the years and pooled basis. The significantly maximum nitrogen uptake in grain was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean nitrogen uptake by grain significantly by 35.48, 24.65 and 6.42 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4.10 and fig 4.5 showed that nitrogen uptake by grain affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum nitrogen uptake by grain was found with dual inoculation of *Azotobacter* + PSB which was 13.82 per cent higher over without inoculation.

Interaction effect of fertility levels and organic manures: The data (Table 4.11) revealed that the interaction between fertility levels and organic manures was found to be significant on nitrogen uptake by grain. The significantly maximum nitrogen uptake by grain (81.37 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum nitrogen uptake by grain (41.16 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.2.17 Nitrogen uptake by straw

Effect of fertility levels: The data presented in Table 4.10 and fig 4.5 revealed that increasing levels of fertilizer significantly influenced the nitrogen uptake by straw over 50 per cent and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum nitrogen uptake by straw was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 per cent RDF resulted in 33.95 and 6.21 per cent increase in nitrogen uptake by straw over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: The data given in Table 4.10 and fig 4.5 showed that the nitrogen uptake by straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum nitrogen uptake by straw was observed with the application of

5 t ha^{-1} vermicompost over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of 5 t vermicompost ha^{-1} increased the mean nitrogen uptake by straw significantly by 25.02, 20.33 and 6.04 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.10 and fig 4.5 revealed that inoculation with biofertilizer significantly affect the nitrogen uptake by straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean nitrogen uptake by straw by 9.40 per cent over no inoculation.

Interaction effect of fertility levels and organic manures: It is clear from the data in Table 4.12 that the interaction between fertility levels and organic manures was found to be significant on nitrogen uptake by straw. The significantly maximum nitrogen uptake by straw (57.01 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum nitrogen uptake by straw (32.74 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.2.18 Total nitrogen uptake

Effect of fertility levels: A perusal of data presented in Table 4.10 and fig 4.5 revealed that fertility level of 100 % RDF significantly influenced the total nitrogen uptake over 50 and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum total nitrogen uptake was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of resulted in 34.57 and 6.36 per cent increase in total nitrogen uptake over 50 and 75 per cent RDF, respectively.

Effect of organic sources: Experimental data given in Table 4.10 and fig 4.5 showed that total nitrogen uptake improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly highest total nitrogen uptake was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @

Table 4.11 Interaction effect of fertility levels and organic manures on N uptake by grain of wheat

Treatments	N uptake by grain (kg ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	44.42	56.21	64.70	37.90	62.90	72.09	41.16	59.56	68.39
FYM (10 t ha^{-1})	63.04	72.36	77.62	60.89	75.69	81.00	61.96	74.02	79.31
VC (2.5 t ha^{-1})	47.39	63.22	66.76	60.02	65.72	64.49	53.70	64.47	65.62
VC (5 t ha^{-1})	62.76	81.24	81.39	64.29	81.50	87.04	63.53	81.37	84.22
SEm±	2.02			3.02			1.28		
CD (P=0.05)	5.76			8.61			3.61		

Table 4.12 Interaction effect of fertility levels and organic manures on N uptake by straw of wheat

Treatments	N uptake by straw (kg ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	35.15	45.11	43.33	30.34	44.83	54.94	32.74	44.97	49.13
FYM (10 t ha^{-1})	39.59	53.64	53.24	49.52	47.96	55.13	44.55	50.80	54.19
VC (2.5 t ha^{-1})	32.75	38.53	58.78	44.46	53.00	36.04	38.60	45.76	47.41
VC (5 t ha^{-1})	46.96	55.50	48.87	36.01	58.50	71.35	41.48	57.00	60.11
SEm±	1.87			2.02			0.97		
CD (P=0.05)	5.34			5.77			2.74		

5 t ha^{-1} increased the mean total nitrogen uptake significantly by 31.01, 22.86 and 6.27 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.10 and fig 4.5 revealed that inoculation with biofertilizer significantly affect the total nitrogen uptake during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean total nitrogen uptake by 11.95 per cent over no inoculation.

Interaction effect of fertility levels and organic manures: It is inferred that the combined application of fertility levels and organic manures on total nitrogen uptake was found to be significant (Table 4.13). The significantly maximum total nitrogen uptake (138.4 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum total nitrogen uptake (73.9 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.2.19 Phosphorus uptake by grain

Effect of fertility levels: A critical examination of data presented in Table 4.14 and fig 4.6 indicated that increasing levels in fertility significantly influenced the phosphorus uptake by grain during both the years of experiment and on pooled basis. The significantly maximum phosphorus uptake by grain was found when soil was enriched with 100 percent RDF over 50 per cent and 75 per cent RDF during both the years and in pooled analysis. The magnitude of mean phosphorus uptake by grain increased by 33.14 and 5.09 per cent due to 100 RDF over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: Data (Table 4.14 and fig 4.6) further showed that phosphorus uptake by grain differed significantly under the influence of different treatments of organic manures during both the years and pooled basis. The significantly maximum phosphorus uptake by grain was observed with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}

during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean phosphorus uptake by grain significantly by 37.19, 25.66 and 7.72 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4.14 and fig 4.6 showed that phosphorus uptake by grain affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum phosphorus uptake by grain was found with dual inoculation of *Azotobacter* + PSB which was 16.68 per cent higher over without inoculation.

Interaction effect of fertility levels and organic manures: The data (Table 4.15) revealed that the interaction between fertility levels and organic manures was found to be significant on phosphorus uptake by grain. The significantly maximum phosphorus uptake by grain (17.92 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum phosphorus uptake by grain (9.14 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.2.20 Phosphorus uptake by straw

Effect of fertility levels: It is apparent from the data presented in Table 4.14 and fig 4.6 that increasing levels of fertilizer significantly influenced the phosphorus uptake by straw over 50 per cent and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum phosphorus uptake in straw was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 per cent RDF resulted in 32.25 and 4.46 per cent increase in phosphorus uptake by straw over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: An examination of data given in Table 4.14 and fig 4.6 revealed that the phosphorus uptake by straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum phosphorus uptake by straw was observed with the application of 5 t ha^{-1} vermicompost over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application

Table 4.13 Interaction effect of fertility levels and organic manures on total N uptake of wheat

Treatments	Total N uptake (kg ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	79.6	101.3	108.0	68.2	107.7	127.0	73.9	104.5	117.5
FYM (10 t ha^{-1})	102.6	126.0	130.9	110.4	123.7	136.1	106.5	124.8	133.5
VC (2.5 t ha^{-1})	80.1	101.7	125.5	104.5	118.7	100.5	92.3	110.2	113.0
VC (5 t ha^{-1})	109.7	136.7	130.3	100.3	140.0	158.4	105.0	138.4	144.3
SEm±	3.32			4.42			1.95		
CD (P=0.05)	9.46			12.60			5.49		

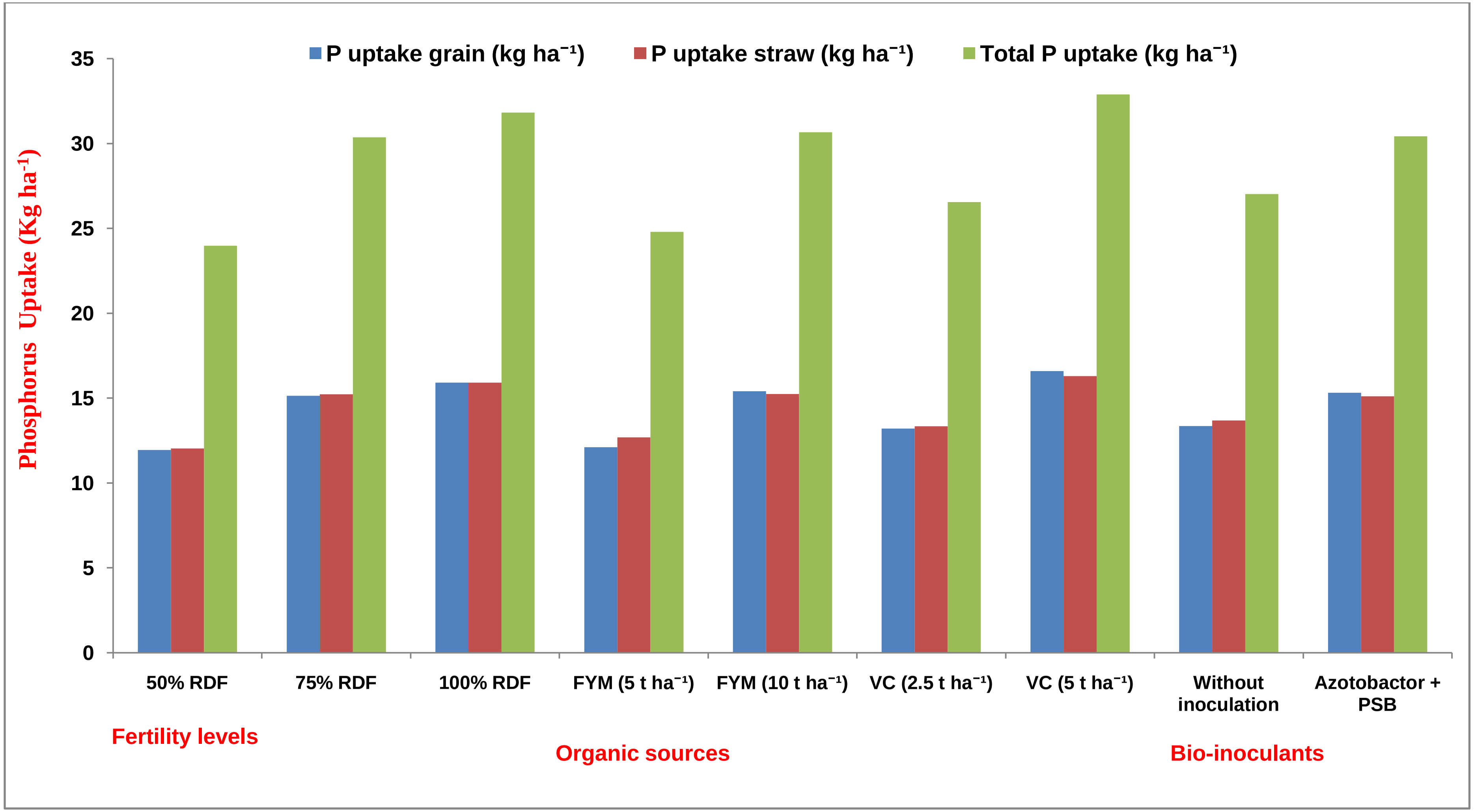


Fig. 4.6 Effect of fertility levels, organic sources and bio-inoculants on phosphorus uptake by wheat (Pooled)

Table 4.14 Effect of fertility levels, organic sources and bio-inoculants on phosphorus uptake by wheat

Treatments	Phosphorus uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels									
50% RDF	11.65	12.25	11.95	11.72	12.34	12.03	23.37	24.60	23.98
75% RDF	14.68	15.60	15.14	14.69	15.77	15.23	29.38	31.36	30.37
100% RDF	15.38	16.43	15.91	15.32	16.51	15.91	30.70	32.94	31.82
SEm ±	0.31	0.36	0.24	0.33	0.36	0.24	0.57	0.64	0.43
CD (P = 0.05)	0.88	1.02	0.66	0.93	1.03	0.69	1.63	1.82	1.20
Organic sources									
FYM (5 t ha^{-1})	11.84	12.36	12.10	12.41	12.97	12.69	24.25	25.34	24.79
FYM (10 t ha^{-1})	15.06	15.77	15.41	14.82	15.67	15.24	29.89	31.43	30.66
VC (2.5 t ha^{-1})	12.54	13.87	13.21	13.01	13.67	13.34	25.55	27.54	26.55
VC (5 t ha^{-1})	16.17	17.04	16.60	15.40	17.18	16.29	31.57	34.22	32.89
SEm ±	0.36	0.41	0.27	0.38	0.42	0.28	0.66	0.74	0.49
CD (P = 0.05)	1.01	1.17	0.76	1.07	1.19	0.79	1.88	2.10	1.39
Bio-inoculants									
Without inoculation	13.03	13.67	13.35	13.22	14.13	13.68	26.25	27.80	27.02
*Azotobacto*r + PSB	14.78	15.85	15.31	14.61	15.61	15.11	29.38	31.46	30.42
SEm ±	0.25	0.29	0.19	0.27	0.30	0.20	0.47	0.52	0.35
CD (P = 0.05)	0.72	0.83	0.54	0.76	0.84	0.56	1.33	1.48	0.98

Table 4.15 Interaction effect of fertility levels and organic manures on P uptake by grain of wheat

Treatments	P uptake by grain (kg ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	9.52	12.05	13.96	8.75	13.67	14.67	9.14	12.86	14.32
FYM (10 t ha^{-1})	13.51	15.50	16.17	13.24	16.46	17.61	13.37	15.98	16.89
VC (2.5 t ha^{-1})	10.16	13.55	13.92	13.05	14.05	14.51	11.60	13.80	14.22
VC (5 t ha^{-1})	13.41	17.63	17.48	13.98	18.21	18.92	13.70	17.92	18.20
SEm±	0.50			0.58			0.27		
CD (P=0.05)	1.43			1.66			0.76		

of 5t vermicompost ha^{-1} increased the mean phosphorus uptake by straw significantly by 28.37, 22.11 and 6.89 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Examination of data presented in Table 4.14 and fig 4.6 further revealed that inoculation with biofertilizer significantly affect the phosphorus uptake by straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean phosphorus uptake by straw by 10.45 per cent over no inoculation.

Interaction effect of fertility levels and organic manures: It is clear from the data in Table 4.16 that the interaction between fertility levels and organic manures was found to be significant on phosphorus uptake by straw. The significantly maximum phosphorus uptake by straw (17.79 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum phosphorus uptake by straw (10.01 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.2.21 Total phosphorus uptake

Effect of fertility levels: An evaluation of data presented in Table 4.14 and fig 4.6 indicated that increasing levels of fertilizer significantly influenced the total phosphorus uptake during both the years of experiment and on pooled basis. The significantly maximum total phosphorus uptake was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 per cent RDF resulted in 32.69 and 4.77 per cent increase in total phosphorus uptake over 50 and 75 per cent RDF, respectively.

Effect of organic sources: Experimental data given in Table 4.14 and fig 4.6 showed that total phosphorus uptake improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly highest total phosphorus uptake was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean total phosphorus uptake significantly by 32.67, 23.88 and

7.27 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.14 and fig 4.6 revealed that inoculation with biofertilizer significantly affect the total phosphorus uptake during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean total phosphorus uptake by 12.58 per cent over no inoculation.

Interaction effect of fertility levels and organic manures: It is inferred that the combined application of fertility levels and organic manures on total phosphorus uptake was found to be significant (Table 4.17). The significantly maximum total phosphorus uptake (35.71 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum total phosphorus uptake (19.14 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.2.22 Potassium uptake by grain

Effect of fertility levels: An examination of data presented in Table 4.18 and fig 4.7 showed that increasing levels in fertility significantly influenced the potassium uptake by grain during both the years of experiment and on pooled basis. The significantly maximum potassium uptake by grain was found when soil was enriched with 100 percent RDF over 50 per cent and 75 per cent RDF during both the years and in pooled analysis. The magnitude of mean potassium uptake by grain increased by 24.80 and 4.01 per cent due to 100 RDF over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: It is apparent from the data given in Table 4.18 and fig 4.7 that potassium uptake by grain significantly influenced by different treatments of organic manures during both the years and pooled basis. The significantly maximum potassium uptake by grain was observed with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean potassium uptake by grain significantly by 27.99, 19.50 and 4.93 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Table 4.16 Interaction effect of fertility levels and organic manures on P uptake by straw of wheat

Treatments	P uptake by straw (kg ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t/ha)	10.67	13.69	12.87	9.34	13.81	15.76	10.01	13.75	14.31
FYM (10 t ha^{-1})	12.02	16.28	16.17	15.25	14.77	16.98	13.63	15.53	16.57
VC (2.5 t ha^{-1})	9.94	11.70	17.40	13.69	16.00	11.31	11.82	13.85	14.36
VC (5 t ha^{-1})	14.26	17.10	14.83	11.09	18.48	21.97	12.67	17.79	18.40
SEm±	0.53			0.59			0.28		
CD (P=0.05)	1.51			1.68			0.79		

Table 4.17 Interaction effect of fertility levels and organic manures on total P uptake of wheat

Treatments	Total P uptake (kg ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	20.19	25.74	26.83	18.09	27.48	30.43	19.14	26.61	28.63
FYM (10 t ha^{-1})	25.53	31.79	32.34	28.49	31.23	34.59	27.01	31.51	33.46
VC (2.5 t ha^{-1})	20.10	25.24	31.33	26.74	30.05	25.83	23.42	27.65	28.58
VC (5 t ha^{-1})	27.67	34.73	32.31	25.07	36.69	40.90	26.37	35.71	36.60
SEm±	0.93			1.04			0.49		
CD (P=0.05)	2.66			2.96			1.39		

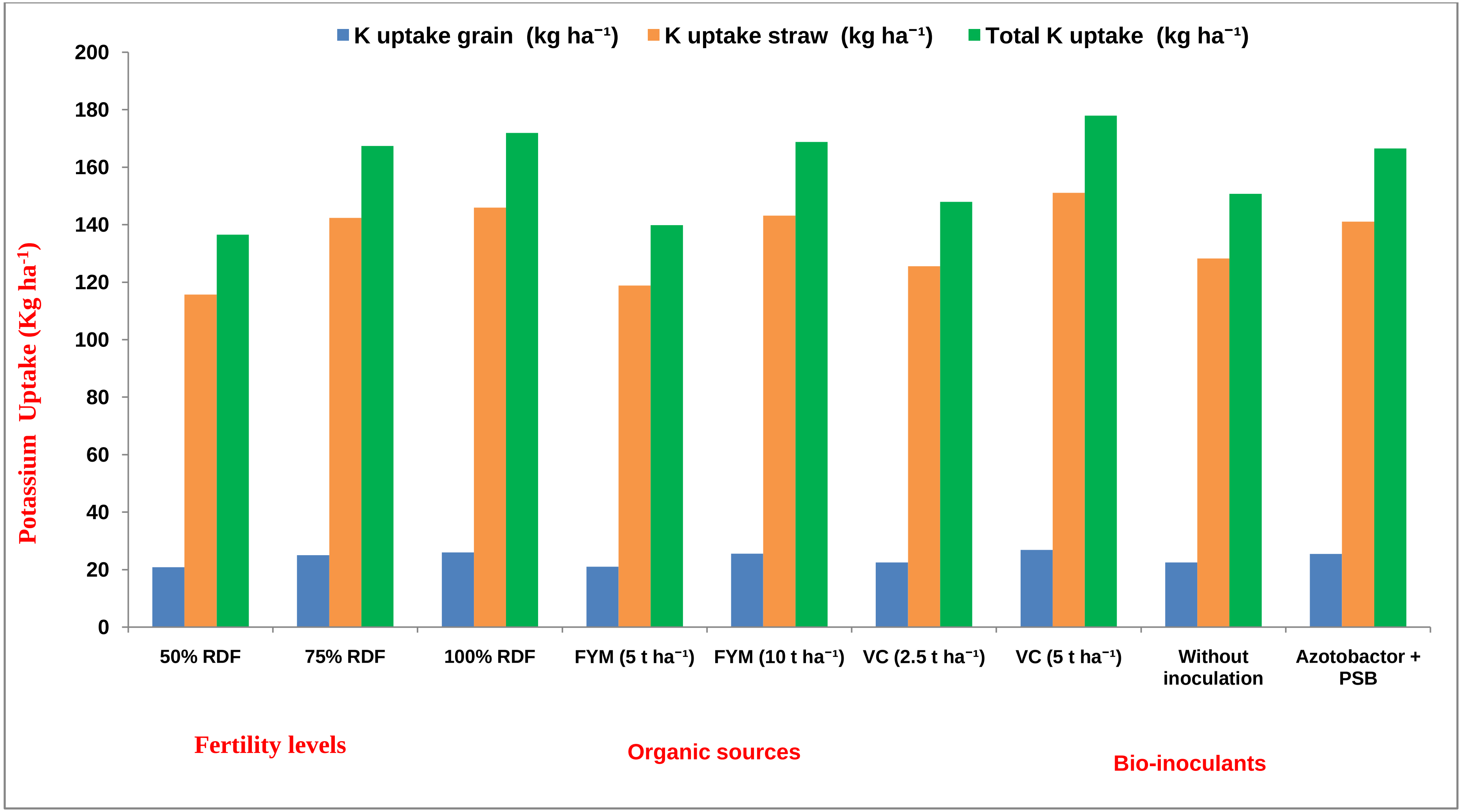


Fig. 4.7 Effect of fertility levels, organic sources and bio-inoculants on potassium uptake by wheat (Pooled)

Table 4.18 Effect of fertility levels, organic sources and bio-inoculants on potassium uptake by wheat

Treatments	Potassium uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels									
50% RDF	20.34	21.36	20.85	114.96	116.37	115.66	135.30	137.73	136.52
75% RDF	24.96	25.07	25.02	139.51	145.27	142.39	164.47	170.35	167.41
100% RDF	25.86	26.18	26.02	143.81	148.03	145.92	169.67	174.21	171.94
SEm ±	0.40	0.60	0.36	2.09	2.44	1.61	2.23	2.74	1.77
CD (P = 0.05)	1.15	1.71	1.01	5.96	6.95	4.52	6.35	7.79	4.96
Organic sources									
FYM (5 t ha^{-1})	20.02	21.92	20.97	117.35	120.34	118.85	137.38	142.26	139.82
FYM (10 t ha^{-1})	25.74	25.42	25.58	141.66	144.67	143.17	167.40	170.10	168.75
VC (2.5 t ha^{-1})	21.60	23.31	22.46	125.44	125.59	125.52	147.04	148.91	147.98
VC (5 t ha^{-1})	27.51	26.17	26.84	146.58	155.62	151.10	174.09	181.79	177.94
SEm ±	0.47	0.69	0.42	2.42	2.82	1.86	2.58	3.16	2.04
CD (P = 0.05)	1.32	1.97	1.17	6.88	8.03	5.22	7.34	8.99	5.72
Bio-inoculants									
Without inoculation	22.32	22.69	22.50	126.73	129.77	128.25	149.05	152.45	150.75
*Azotobacto*r + PSB	25.12	25.73	25.42	138.79	143.34	141.07	163.90	169.07	166.49
SEm ±	0.33	0.49	0.29	1.71	1.99	1.31	1.82	2.23	1.44
CD (P = 0.05)	0.94	1.39	0.83	4.87	5.68	3.69	5.19	6.36	4.05

Effect of bio-inoculants: Data presented in Table 4.18 and fig 4.7 further showed that potassium uptake by grain affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum potassium uptake by grain was found with dual inoculation of *Azotobacter* + PSB which was 12.98 per cent higher over without inoculation.

Interaction effect of fertility levels and organic manures: The data (Table 4.19) revealed that the interaction between fertility levels and organic manures was found to be significant on potassium uptake by grain. The significantly maximum potassium uptake by grain (28.97 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum potassium uptake by grain (19.60 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.2.23 Potassium uptake by straw

Effect of fertility levels: A perusal of data presented in Table 4.18 and fig 4.7 revealed that increasing levels of fertilizer significantly influenced the potassium uptake by straw over 50 per cent and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum potassium uptake in straw was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. The per cent increase in potassium uptake by straw due to application of 100 per cent RDF were 26.16 and 2.48 per cent over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: A critical examination of data given in Table 4.18 and fig 4.7 revealed that the potassium uptake by straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum potassium uptake by straw was observed with the application of 5 t ha^{-1} vermicompost over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of 5 t vermicompost ha^{-1} increased the mean potassium uptake by straw significantly by 27.14, 20.38 and 5.54 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.18 and fig 4.7 revealed that inoculation with biofertilizer significantly affect the potassium uptake by straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean potassium uptake by straw by 10.01 per cent over no inoculation.

Interaction effect of fertility levels and organic manures: It is clear from the data in Table 4.20 that the interaction between fertility levels and organic manures was found to be significant on potassium uptake by straw. The significantly maximum potassium uptake by straw (164.4 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum potassium uptake by straw (106.6 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.2.24 Total potassium uptake

Effect of fertility levels: An evaluation of data presented in Table 4.18 and fig 4.7 indicated that increasing levels of fertilizer significantly influenced the total potassium uptake during both the years of experiment and on pooled basis. The significantly maximum total potassium uptake was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 per cent RDF resulted in 25.94 and 2.71 per cent increase in total potassium uptake over 50 and 75 per cent RDF, respectively.

Effect of organic sources: A perusal of data presented in Table 4.18 and fig 4.7 revealed that total potassium uptake improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly highest total potassium uptake was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean total potassium uptake significantly by 27.26, 20.25 and 5.45 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Table 4.19 Interaction effect of fertility levels and organic manures on K uptake by grain of wheat

Treatments	K uptake by grain (kg ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	17.00	20.48	22.59	22.20	22.60	20.97	19.60	21.54	21.78
FYM (10 t ha^{-1})	23.38	26.36	27.50	20.53	27.82	27.92	21.95	27.09	27.71
VC (2.5 t ha^{-1})	18.11	23.03	23.67	18.85	21.91	29.18	18.48	22.47	26.42
VC (5 t ha^{-1})	22.89	29.97	29.67	23.87	27.96	26.67	23.38	28.97	28.17
SEm±	0.65			0.97			0.41		
CD (P=0.05)	1.87			2.78			1.17		

Table 4.20 Interaction effect of fertility levels and organic manures on K uptake by straw of wheat

Treatments	K uptake by straw (kg ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	107.0	130.4	114.7	106.3	126.3	128.4	106.6	128.3	121.6
FYM (10 t ha^{-1})	116.0	155.0	153.9	129.1	153.8	151.1	122.6	154.4	152.5
VC (2.5 t ha^{-1})	100.8	109.8	165.7	114.7	135.0	127.0	107.8	122.4	146.4
VC (5 t ha^{-1})	136.0	162.8	140.9	115.4	165.9	185.5	125.7	164.4	163.2
SEm±	3.41			3.98			1.85		
CD (P=0.05)	9.73			11.35			5.21		

Effect of bio-inoculants: Further examination of data presented in Table 4.18 and fig 4.7 revealed that inoculation with biofertilizer significantly affect the total potassium uptake during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean total potassium uptake by 10.44 per cent over no inoculation.

Interaction effect of fertility levels and organic manures: It is inferred that the combined application of fertility levels and organic manures on total potassium uptake was found to be significant (Table 4.21). The significantly maximum total potassium uptake (193.3 q ha^{-1}) was recorded with combined application of vermicompost @ 5 t ha^{-1} + 75 per cent RDF over other treatments but remained at par with vermicompost @ 5 t ha^{-1} + 100 per cent RDF. The minimum total potassium uptake (126.2 q ha^{-1}) was obtained under the treatments involving application of FYM @ 5 t ha^{-1} + 50 per cent RDF.

4.1.2.25 Iron uptake by grain

Effect of fertility levels: Increasing levels in fertility significantly influenced the iron uptake by grain during both the years of experimentation and on pooled basis (Table 4.22 and fig 4.8). The significantly maximum iron uptake by grain was found with 100 percent RDF over 50 per cent and 75 per cent RDF during both the years and in pooled analysis. The per cent increase in mean iron uptake by grain due to 100 RDF were 25.91 and 5.22 per cent over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: The data given in Table 4.22 and fig 4.8 showed that iron uptake by grain significantly influenced by different treatments of organic manures during both the years and pooled basis. The significantly maximum iron uptake by grain was observed with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. The magnitude of percent increase in mean iron uptake by grain due to 5 t vermicompost ha^{-1} by 35.38, 24.07 and 5.77 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4.22 and fig 4.8 further showed that iron uptake by grain affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum iron uptake by grain was found with dual inoculation of *Azotobacter* + PSB which was 9.49 per cent higher over without inoculation.

4.1.2.26 Iron uptake by straw

Effect of fertility levels: An appraisal of data presented in Table 4.22 and fig 4.8 indicated that increasing levels of fertilizer significantly influenced the iron uptake by straw over 50 per cent and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum iron uptake in straw was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. The per cent increase in iron uptake by straw due to application of 100 per cent RDF were 23.18 and 3.61 per cent over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: A critical examination of data given in Table 4.22 and fig 4.8 revealed that the iron uptake by straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum iron uptake by straw was observed with the application of 5 t ha^{-1} vermicompost over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. The application of 5 t vermicompost ha^{-1} increased the mean iron uptake by straw significantly by 25.65, 20.63 and 6.07 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.22 and fig 4.8 revealed that inoculation with biofertilizer significantly affect the iron uptake by straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean iron uptake by straw by 7.86 per cent over no inoculation.

4.1.2.27 Total iron uptake

Effect of fertility levels: An evaluation of data presented in Table 4.22 and fig 4.8 indicated that increasing levels of fertilizer significantly influenced the total iron uptake during both the years of experiment and on pooled basis. The significantly maximum total iron uptake was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis.

Table 4.21 Interaction effect of fertility levels and organic manures on total K uptake of wheat

Treatments	Total K uptake (kg ha^{-1})								
	2015-16			2016-17			Pooled		
	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
FYM (5 t ha^{-1})	124.0	150.8	137.3	128.5	148.9	149.4	126.2	149.9	143.4
FYM (10 t ha^{-1})	139.4	181.4	181.4	149.6	181.6	179.1	144.5	181.5	180.2
VC (2.5 t ha^{-1})	118.9	132.9	189.4	133.6	157.0	156.2	126.2	144.9	172.8
VC (5 t ha^{-1})	158.9	192.8	170.6	139.3	193.9	212.2	149.1	193.3	191.4
SEm±	3.64			4.46			2.03		
CD (P=0.05)	10.37			12.71			5.72		

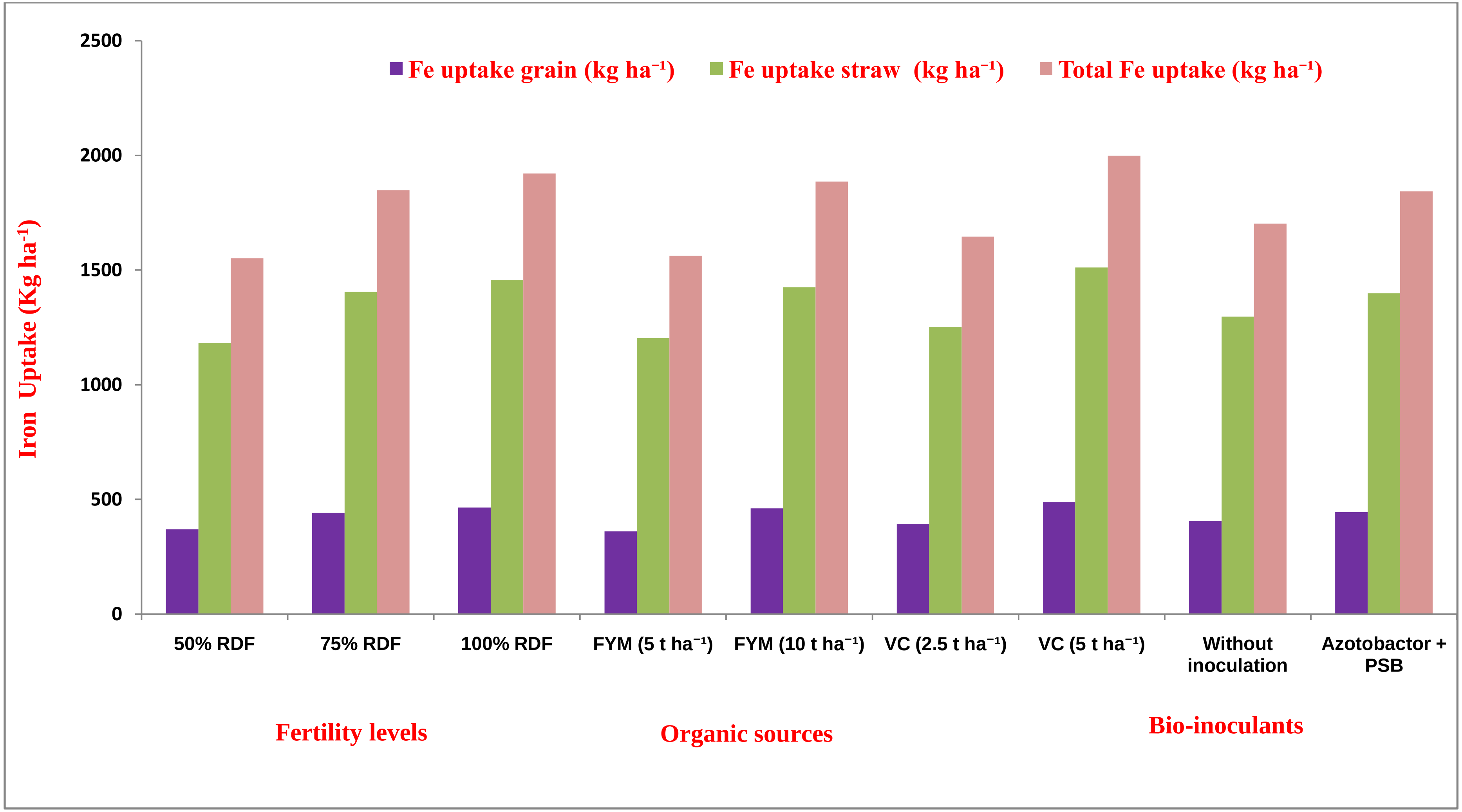


Fig. 4.8 Effect of fertility levels, organic sources and bio-inoculants on iron uptake by wheat (Pooled)

Table 4.22 Effect of fertility levels, organic sources and bio-inoculants on Iron uptake by wheat

Treatments	Iron uptake (g ha^{-1})								
	Grain			Straw			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels									
50% RDF	361.87	376.57	369.22	1174.4	1189.5	1182.0	1536.3	1566.1	1551.2
75% RDF	431.33	452.33	441.83	1378.3	1432.4	1405.3	1809.6	1884.7	1847.2
100% RDF	452.65	477.12	464.89	1438.1	1473.8	1456.0	1890.7	1951.0	1920.9
SEm ±	6.81	10.78	6.37	19.54	22.81	15.02	21.33	27.73	17.49
CD (P = 0.05)	19.40	30.68	17.90	55.62	64.93	42.18	60.72	78.94	49.13
Organic sources									
FYM (5 t ha^{-1})	353.16	366.95	360.06	1183.1	1222.2	1202.6	1536.2	1589.2	1562.7
FYM (10 t ha^{-1})	451.15	470.57	460.86	1415.2	1433.9	1424.6	1866.3	1904.5	1885.4
VC (2.5 t ha^{-1})	376.15	409.59	392.87	1250.9	1254.6	1252.7	1627.0	1664.2	1645.6
VC (5 t ha^{-1})	480.66	494.25	487.45	1471.9	1550.3	1511.1	1952.5	2044.5	1998.5
SEm ±	7.87	12.44	7.36	22.56	26.34	17.34	24.63	32.02	20.20
CD (P = 0.05)	22.40	35.42	20.67	64.22	74.98	48.70	70.11	91.16	56.73
Bio-inoculants									
Without inoculation	396.24	415.87	406.05	1284.9	1308.7	1296.8	1681.1	1724.5	1702.8
*Azotobacto*r + PSB	434.33	454.81	444.57	1375.7	1421.8	1398.7	1810.0	1876.6	1843.3
SEm ±	5.56	8.80	5.20	15.95	18.62	12.26	17.41	22.64	14.28
CD (P = 0.05)	15.84	25.05	14.62	45.41	53.02	34.44	49.57	64.46	40.12

Application of 100 per cent RDF resulted in 23.83 and 3.99 per cent increase in total iron uptake over 50 and 75 per cent RDF, respectively.

Effect of organic sources: The data presented in Table 4.22 and fig 4.8 revealed that total iron uptake improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly highest total iron uptake was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean total iron uptake significantly by 27.89, 21.45 and 6.01 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.22 and fig 4.8 revealed that inoculation with biofertilizer significantly affect the total iron uptake during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean total iron uptake by 8.25 per cent over no inoculation.

4.1.2.28 Manganese uptake by grain

Effect of fertility levels: Increasing levels in fertility significantly influenced the manganese uptake by grain during both the years of experimentation and on pooled basis (Table 4.23 and fig 4.9). The significantly maximum manganese uptake by grain was found with 100 percent RDF over 50 per cent and 75 per cent RDF during both the years and in pooled analysis. The per cent increase in mean manganese uptake by grain due to 100 RDF were 33.45 and 6.39 per cent over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: The data given in Table 4. 23 and fig 4.9 showed that manganese uptake by grain significantly influenced by different treatments of organic manures during both the years and pooled basis. The significantly maximum manganese uptake by grain was observed with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. The magnitude of percent increase in mean manganese uptake by grain due to 5 t vermicompost ha^{-1} by 35.69, 23.35 and 6.35 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4. 23 and fig 4.9 further showed that manganese uptake by grain affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum manganese uptake by grain was found with dual inoculation of *Azotobacter* + PSB which was 13.53 per cent higher over without inoculation.

4.1.2.29 Manganese uptake by straw

Effect of fertility levels: A perusal of data (Table 4. 23 and fig 4.9) revealed that increasing levels of fertilizer significantly influenced the manganese uptake by straw over 50 per cent and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum manganese uptake in straw was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. The per cent increase in manganese uptake by straw due to application of 100 per cent RDF were 31.71 and 4.14 per cent over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: A critical examination of data given in Table 4. 23 and fig 4.9 revealed that the manganese uptake by straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum manganese uptake by straw was observed with the application of 5 t ha^{-1} vermicompost over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. The application of 5t vermicompost ha^{-1} increased the mean manganese uptake by straw significantly by 24.48, 21.15 and 6.10 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: An examination of data presented in Table 4. 23 and fig 4.9 showed that inoculation with biofertilizer significantly affect the manganese uptake by straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean manganese uptake by straw by 6.61 per cent over no inoculation.

4.1.2.30 Total manganese uptake

Effect of fertility levels: An evaluation of data presented in Table 4. 23 and fig 4.9 indicated that increasing levels of fertilizer significantly influenced the total manganese uptake during both the years of experiment and on pooled basis. The significantly maximum total manganese uptake was found with 100 per cent RDF

Table 4.23 Effect of fertility levels, organic sources and bio-inoculants on Manganese uptake by wheat

Treatments	Manganese uptake (g ha^{-1})								
	Grain			Straw			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels									
50% RDF	56.4	58.4	57.4	156.8	167.9	162.4	213.2	226.3	219.8
75% RDF	70.1	73.9	72.0	197.5	213.3	205.4	267.6	287.2	277.4
100% RDF	74.1	79.0	76.6	204.0	223.7	213.9	278.2	302.6	290.4
SEm ±	1.2	1.8	1.1	3.7	4.9	3.1	4.3	6.1	3.7
CD (P = 0.05)	3.5	5.1	3.0	10.6	14.1	8.7	12.4	17.3	10.5
Organic sources									
FYM (5 t ha^{-1})	56.3	59.8	58.0	169.0	179.9	174.4	225.3	239.7	232.5
FYM (10 t ha^{-1})	73.3	74.8	74.0	197.8	211.7	204.8	271.1	286.5	278.8
VC (2.5 t ha^{-1})	61.3	66.3	63.8	174.1	184.3	179.2	235.4	250.6	243.0
VC (5 t ha^{-1})	76.6	80.7	78.7	203.6	230.6	217.1	280.2	311.4	295.8
SEm ±	1.4	2.1	1.3	4.3	5.7	3.6	5.0	7.0	4.3
CD (P = 0.05)	4.0	5.9	3.5	12.3	16.2	10.0	14.3	20.0	12.1
Bio-inoculants									
Without inoculation	62.3	66.3	64.3	180.0	195.3	187.7	242.3	261.5	251.9
*Azotobacto*r + PSB	71.5	74.5	73.0	192.2	208.0	200.1	263.7	282.5	273.1
SEm ±	1.0	1.5	0.9	3.1	4.0	2.5	3.5	5.0	3.0
CD (P = 0.05)	2.8	4.2	2.5	8.7	11.5	7.1	10.1	14.1	8.6

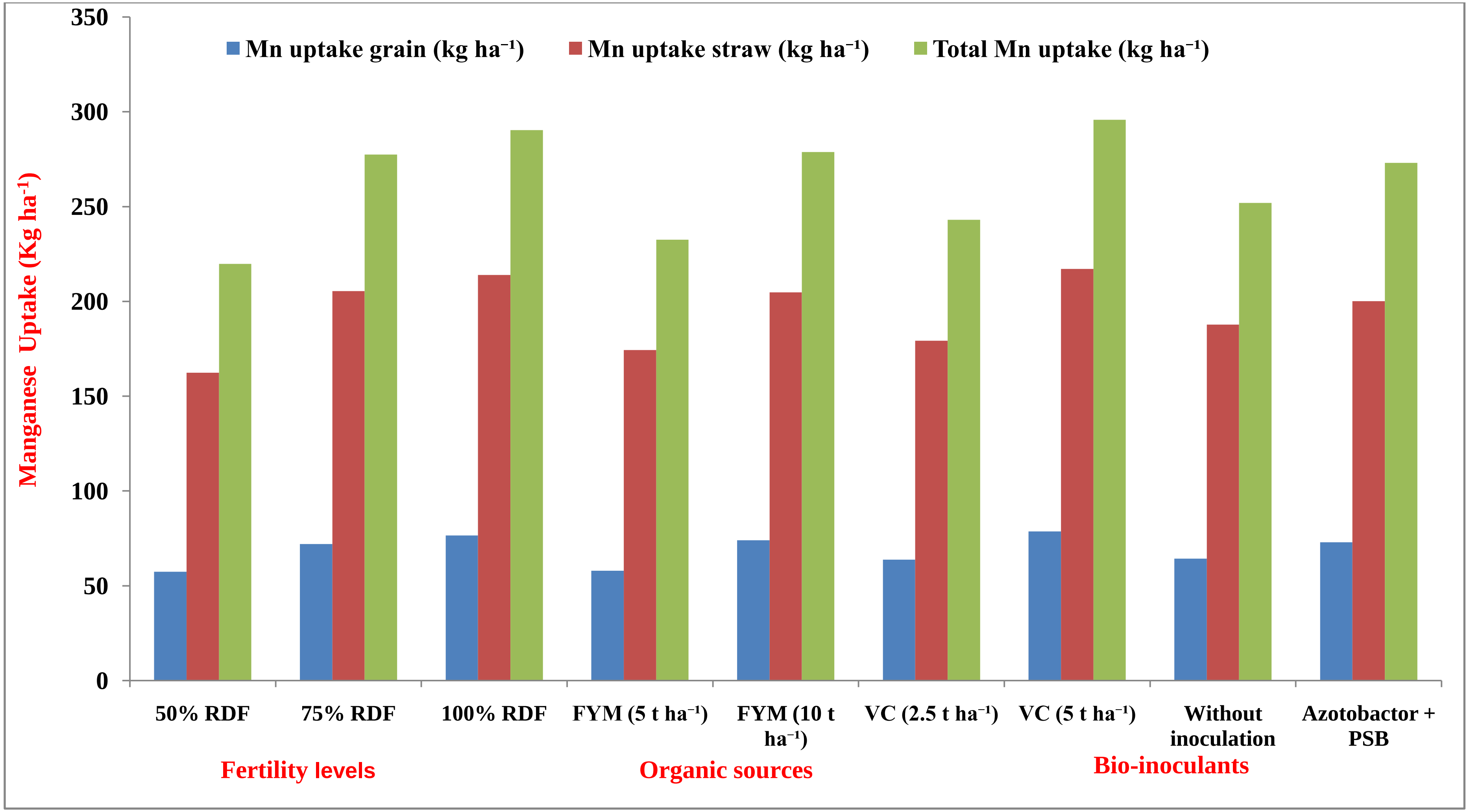


Fig. 4.9 Effect of fertility levels, organic sources and bio-inoculants on manganese uptake by wheat (Pooled)

over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 per cent RDF resulted in 32.12 and 4.69 per cent increase in total manganese uptake over 50 and 75 per cent RDF, respectively.

Effect of organic sources: The data presented in Table 4. 23 and fig 4.9 revealed that total manganese uptake improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly highest total manganese uptake was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean total manganese uptake significantly by 27.23, 21.73 and 6.10 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4. 23 and fig 4.9 revealed that inoculation with biofertilizer significantly affect the total manganese uptake during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean total manganese uptake by 8.42 per cent over no inoculation.

4.1.2.31 Zinc uptake by grain

Effect of fertility levels: An examination of data presented in Table 4.24 and fig 4.10 revealed that increasing levels of fertilizer significantly influenced the zinc uptake by grain during both the years of experiment and on pooled basis. The significantly maximum zinc uptake by grain was found when soil was enriched with 100 percent RDF over 50 per cent and 75 per cent RDF during both the years and in pooled analysis. The magnitude of mean zinc uptake by grain increased by 32.75 and 5.83 per cent due to 100 RDF over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: Zinc uptake by grain under the influence of different treatments of organic manures is presented in Table 4.24 and fig 4.10 revealed that the application of different organic manures differed significantly during both the years and pooled basis. The significantly maximum zinc uptake in grain was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of 5t vermicompost ha^{-1} increased the mean zinc uptake by grain significantly by 35.75, 23.90 and 6.99 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4.24 and fig 4.10 showed that zinc uptake by grain affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum zinc uptake by grain was found with dual inoculation of *Azotobacter* + PSB which was 13.55 percent higher over without inoculation.

4.1.2.32 Zinc uptake by straw

Effect of fertility levels: The data presented in Table 4.24 and fig 4.10 revealed that increasing levels of fertilizer significantly influenced the zinc uptake by straw over 50 per cent and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum zinc uptake by straw was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 per cent RDF resulted in 32.89 and 5.37 per cent increase in zinc uptake by straw over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: The data given in Table 4.24 and fig 4.10 showed that the zinc uptake by straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum zinc uptake by straw was observed with the application of 5 t ha^{-1} vermicompost over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of 5 t vermicompost ha^{-1} increased the mean zinc uptake by straw significantly by 27.60, 20.45 and 5.43 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.24 and fig 4.10 revealed that inoculation with biofertilizer significantly affect the zinc uptake by straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean zinc uptake by straw by 9.81 per cent over no inoculation.

4.1.2.33 Total zinc uptake

Effect of fertility levels: A perusal of data presented in Table 4.24 and fig 4.10 revealed that fertility level of 100% RDF significantly influenced the total zinc uptake

Table 4.24 Effect of fertility levels, organic sources and bio-inoculants on Zinc uptake by wheat

Treatments	Zinc uptake (g ha^{-1})								
	Grain			Straw			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels									
50% RDF	112.8	116.8	114.8	133.5	138.3	135.9	246.3	255.0	250.7
75% RDF	140.2	147.7	144.0	166.1	176.7	171.4	306.2	324.5	315.4
100% RDF	147.5	157.3	152.4	174.8	186.4	180.6	322.3	343.7	333.0
SEm ±	2.8	3.6	2.3	3.3	4.1	2.7	5.3	6.7	4.3
CD (P = 0.05)	8.0	10.3	6.4	9.5	11.7	7.5	15.2	19.1	12.0
Organic sources									
FYM (5 t ha^{-1})	112.6	119.6	116.1	138.1	148.1	143.1	250.6	267.7	259.2
FYM (10 t ha^{-1})	145.1	149.5	147.3	168.9	177.5	173.2	314.1	327.0	320.5
VC (2.5 t ha^{-1})	121.9	132.6	127.2	149.7	153.5	151.6	271.5	286.1	278.8
VC (5 t ha^{-1})	154.6	160.7	157.6	175.7	189.4	182.6	330.3	350.1	340.2
SEm ±	3.3	4.2	2.6	3.9	4.8	3.1	6.1	7.7	4.9
CD (P = 0.05)	9.3	11.9	7.4	11.0	13.5	8.6	17.5	22.0	13.9
Bio-inoculants									
Without inoculation	124.2	132.5	128.4	149.1	160.9	155.0	273.3	293.5	283.4
*Azotobacto*r + PSB	142.9	148.7	145.8	167.1	173.4	170.2	310.0	322.0	316.0
SEm ±	2.3	3.0	1.9	2.7	3.4	2.2	4.3	5.5	3.5
CD (P = 0.05)	6.5	8.4	5.3	7.8	9.6	6.1	12.4	15.6	9.8

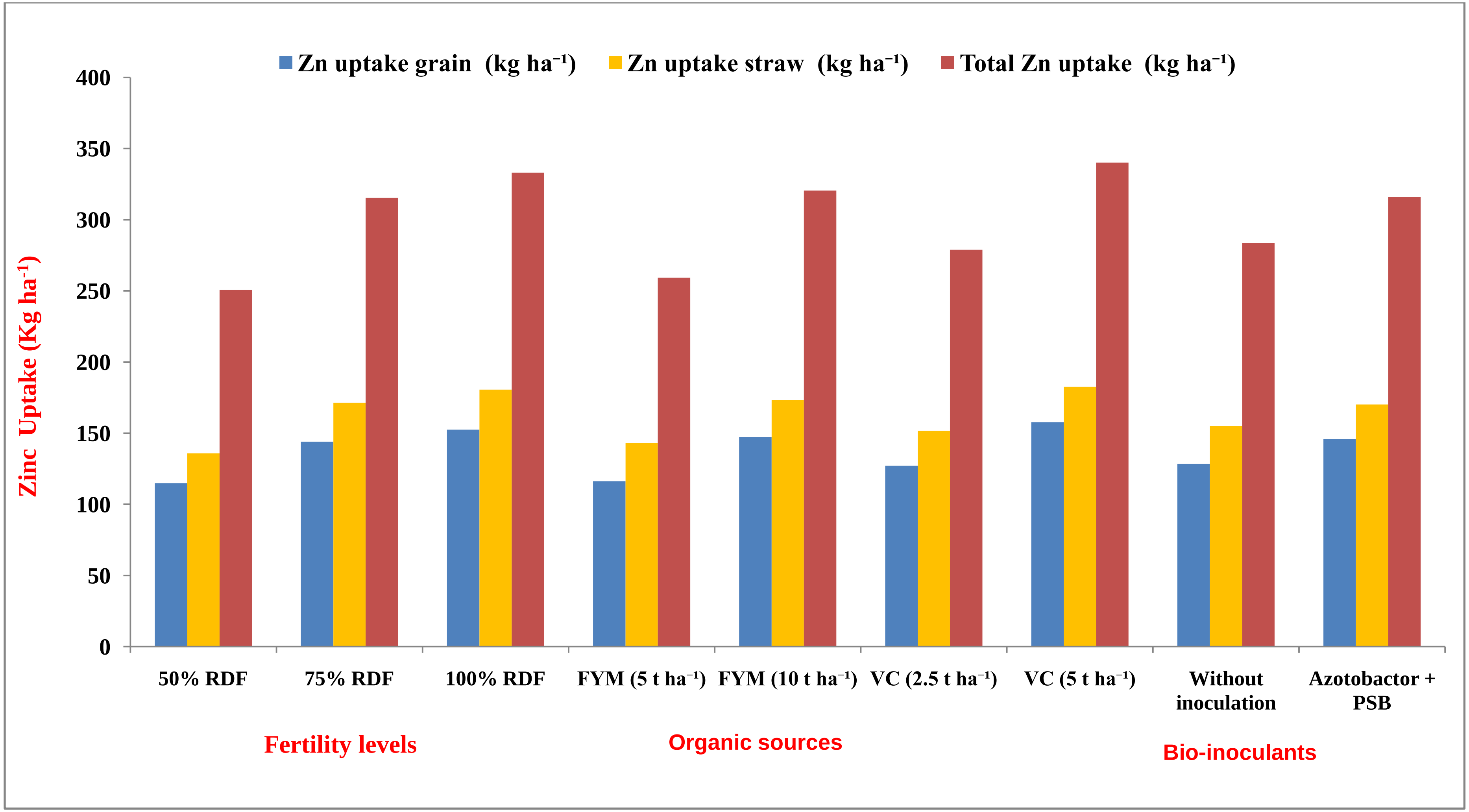


Fig. 4.10 Effect of fertility levels, organic sources and bio-inoculants on zinc uptake by wheat (Pooled)

over 50 and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum total zinc uptake was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of resulted in 32.83 and 5.58 per cent increase in total zinc uptake over 50 and 75 per cent RDF, respectively.

Effect of organic sources: Experimental data given in Table 4.24 and fig 4.10 showed that total zinc uptake improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly highest total zinc uptake was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean total zinc uptake significantly by 31.25, 22.02 and 6.15 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.24 and fig 4.10 revealed that inoculation with biofertilizer significantly affect the total zinc uptake during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean total zinc uptake by 11.50 per cent over no inoculation.

4.1.2.34 Copper uptake by grain

Effect of fertility levels: A critical examination of data presented in Table 4.25 and fig 4.11 indicated that increasing levels of fertilizer significantly influenced the copper uptake by grain during both the years of experiment and on pooled basis. The significantly maximum copper uptake by grain was found when soil was enriched with 100 percent RDF over 50 per cent and 75 per cent RDF during both the years and in pooled analysis. The magnitude of mean copper uptake by grain increased by 32.39 and 6.21 per cent due to 100 RDF over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: Copper uptake by grain under the influence of different treatments of organic manures are presented in Table 4.25 and fig 4.11 revealed that the application of different organic manures differed significantly with respect to copper uptake by grain during both the years and pooled basis. The significantly maximum copper uptake in grain was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1}

increased the mean copper uptake by grain significantly by 34.03, 23.32 and 5.75 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Data presented in Table 4.25 and fig 4.11 showed that copper uptake by grain affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum copper uptake by grain was found with dual inoculation of *Azotobacter* + PSB which was 13.61 per cent higher over without inoculation.

4.1.2.35 Copper uptake by straw

Effect of fertility levels: The data presented in Table 4.25 and fig 4.11 revealed that increasing levels of fertilizer significantly influenced the copper uptake by straw over 50 per cent and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum copper uptake by straw was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of 100 per cent RDF resulted in 31.66 and 4.92 per cent increase in copper uptake by straw over 50 per cent and 75 per cent RDF, respectively.

Effect of organic sources: Data (Table 4.25 and fig 4.11) showed that the copper uptake by straw improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly maximum copper uptake by straw was observed with the application of 5 t ha^{-1} vermicompost over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of 5 t vermicompost ha^{-1} increased the mean copper uptake by straw significantly by 30.26, 23.01 and 9.63 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.25 and fig 4.11 revealed that inoculation with biofertilizer significantly affect the copper uptake by straw during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobactor* + PSB significantly increased the mean copper uptake by straw by 12.4 per cent over no inoculation.

4.1.2.36 Total copper uptake

Effect of fertility levels: A perusal of data presented in Table 4.25 and fig 4.11 revealed that fertility level of 100 % RDF significantly influenced the total copper

Table 4.25 Effect of fertility levels, organic sources and bio-inoculants on Copper uptake by wheat

Treatments	Copper uptake (g ha^{-1})								
	Grain			Straw			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels									
50% RDF	27.8	28.9	28.4	25.5	26.3	25.9	53.3	55.3	54.3
75% RDF	34.5	36.4	35.4	31.3	33.6	32.5	65.7	70.0	67.9
100% RDF	36.4	38.7	37.6	32.6	35.6	34.1	69.0	74.2	71.6
SEm ±	0.6	0.9	0.5	0.6	0.8	0.5	1.0	1.5	0.9
CD (P = 0.05)	1.8	2.5	1.5	1.6	2.4	1.4	2.9	4.1	2.5
Organic sources									
FYM (5 t ha^{-1})	28.1	29.5	28.8	26.1	28.1	27.1	54.2	57.5	55.9
FYM (10 t ha^{-1})	35.9	37.0	36.5	31.2	33.2	32.2	67.1	70.3	68.7
VC (2.5 t ha^{-1})	29.9	32.7	31.3	28.3	29.2	28.7	58.2	61.8	60.0
VC (5 t ha^{-1})	37.7	39.5	38.6	33.6	36.9	35.3	71.3	76.4	73.9
SEm ±	0.7	1.0	0.6	0.7	1.0	0.6	1.2	1.7	1.0
CD (P = 0.05)	2.1	2.9	1.8	1.9	2.7	1.6	3.3	4.8	2.9
Bio-inoculants									
Without inoculation	30.6	32.6	31.6	27.5	30.5	29.0	58.1	63.2	60.7
*Azotobacto*r + PSB	35.2	36.7	35.9	32.1	33.2	32.6	67.3	69.9	68.6
SEm ±	0.5	0.7	0.4	0.5	0.7	0.4	0.8	1.2	0.7
CD (P = 0.05)	1.5	2.1	1.2	1.3	1.9	1.2	2.4	3.4	2.0

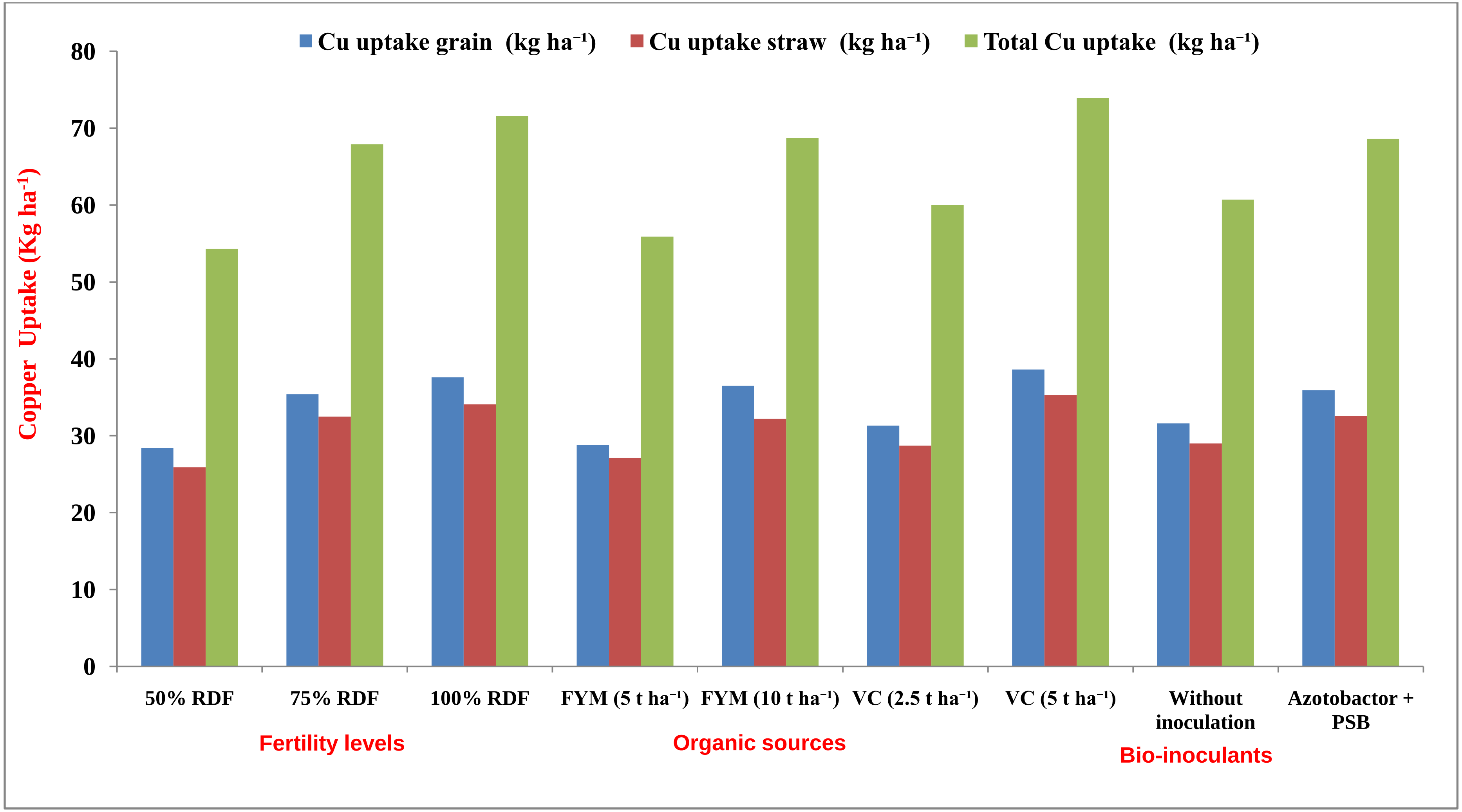


Fig. 4.11 Effect of fertility levels, organic sources and bio-inoculants on copper uptake by wheat (Pooled)

uptake over 50 and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum total copper uptake was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of resulted in 31.86 and 5.45 per cent increase in total nitrogen copper over 50 and 75 per cent RDF, respectively.

Effect of organic sources: It is apparent from the data given in Table 4.25 and fig 4.11 that total copper uptake improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly highest total copper uptake was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean total copper uptake significantly by 32.20, 23.17 and 7.57 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.25 and fig 4.11 revealed that inoculation with biofertilizer significantly affect the total copper uptake during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean total copper uptake by 13.01 per cent over no inoculation.

4.1.3 Physico-chemical Properties of Soil

4.1.3.1 Bulk density

Effect of fertility levels: The data presented in Table 4.26 showed that bulk density of soil ranges between (1.43, 1.45 and 1.44 Mg m^{-3}) at 50 per cent, (1.41, 1.43 and 1.42 Mg m^{-3}) at 75 per cent and (1.40, 1.43 and 1.42 Mg m^{-3}) at 100 per cent RDF which emphasized that bulk density of soil was not influenced significantly due to the application of increasing levels of fertilizer during both the years as well as in pooled analysis.

Effect of organic sources: A perusal of data (Table 4.26) showed that bulk density of soil ranges between (1.40, 1.43 and 1.41 Mg m^{-3}) at 5 t FYM ha^{-1}, (1.44, 1.46 and 1.45 Mg m^{-3}) at 10 t FYM ha^{-1}, (1.39, 1.42 and 1.41 Mg m^{-3}) at 5 t vermicompost ha^{-1} and (1.43, 1.44 and 1.43 Mg m^{-3}) at 10 t vermicompost ha^{-1} which was not influenced significantly due to application of different treatments of organic manures during both the years as well as in pooled analysis.

Effect of bio-inoculants: Data (Table 4.26) further revealed that bulk density of soil ranges between (1.41, 1.43 and 1.42 Mg m^{-3}) at without inoculation and (1.42, 1.44 and 1.43 Mg m^{-3}) at when seeds were inoculated with *Azotobacter* + PSB which showed that bulk density was not influenced significantly due to the inoculation of biofertilizer during both the years as well as in pooled basis.

4.1.3.2 Particle density

Effect of fertility levels: A perusal of data presented in Table 4.26 showed that particle density of soil ranges between (2.51, 2.53 and 2.52 Mg m^{-3}) at 50 per cent, (2.49, 2.51 and 2.50 Mg m^{-3}) at 75 per cent and (2.48, 2.50 and 2.49 Mg m^{-3}) at 100 per cent RDF which emphasized that particle density of soil was not influenced significantly due to the application of increasing levels of fertilizer during both the years as well as in pooled analysis.

Effect of organic sources: A critical examination of data (Table 4.26) revealed that particle density of soil of soil ranges between (2.46, 2.49 and 2.48 Mg m^{-3}) at 5 t FYM ha^{-1}, (2.55, 2.56 and 2.56 Mg m^{-3}) at 10 t FYM ha^{-1}, (2.45, 2.47 and 2.46 Mg m^{-3}) at 5 t vermicompost ha^{-1} and (2.52, 2.51 and 2.52 Mg m^{-3}) at 10 t vermicompost ha^{-1} which was not influenced significantly due to application of different treatments of organic manures during both the years as well as in pooled analysis.

Effect of bio-inoculants: Data (Table 4.26) further revealed that particle density of soil ranges between (2.49, 2.51 and 2.50 Mg m^{-3}) at without inoculation and (2.50, 2.52 and 2.51 Mg m^{-3}) at when seeds were inoculated with *Azotobacter* + PSB which showed that bulk density was not influenced significantly due to the inoculation of biofertilizer during both the years as well as in pooled basis.

4.1.3.3 Porosity

Effect of fertility levels: The data presented in Table 4.26 showed that porosity of soil was not influenced significantly due to the application of increasing levels of fertilizer during both the years as well as in pooled analysis.

Effect of organic sources: A perusal of data (Table 4.26) showed that porosity of soil was not influenced significantly due to application of different treatments of organic manures during both the years as well as in pooled analysis.

Table 4.26 Effect of fertility levels, organic sources and bio-inoculants on bulk density, particle density, water holding capacity and porosity of soil

Treatments	Bulk density (Mg m^{-3})			Particle density (Mg m^{-3})			Porosity (%)			Water holding capacity (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels												
50% RDF	1.43	1.45	1.44	2.51	2.53	2.52	43.09	42.76	42.92	42.33	44.74	43.53
75% RDF	1.41	1.43	1.42	2.49	2.51	2.50	43.27	42.95	43.11	44.30	46.81	45.55
100% RDF	1.40	1.43	1.42	2.48	2.50	2.49	43.39	42.86	43.13	45.97	48.27	47.12
SEm ±	0.007	0.005	0.004	0.014	0.011	0.009	0.193	0.197	0.138	0.36	0.38	0.26
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.02	1.09	0.74
Organic sources												
FYM (5 t ha^{-1})	1.40	1.43	1.41	2.46	2.49	2.48	43.04	42.86	42.95	42.35	44.46	43.40
FYM (10 t ha^{-1})	1.44	1.46	1.45	2.55	2.56	2.56	43.48	43.11	43.30	43.28	45.84	44.56
VC (2.5 t ha^{-1})	1.39	1.42	1.41	2.45	2.47	2.46	43.18	42.47	42.83	44.58	47.20	45.89
VC (5 t ha^{-1})	1.43	1.44	1.43	2.52	2.51	2.52	43.31	42.98	43.14	46.59	48.92	47.76
SEm ±	0.008	0.006	0.005	0.016	0.012	0.010	0.223	0.228	0.159	0.41	0.44	0.30
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.18	1.26	0.85
Bio-inoculants												
Without inoculation	1.41	1.43	1.42	2.49	2.51	2.50	43.29	42.92	43.11	43.53	46.09	44.81
*Azotobacto*r + PSB	1.42	1.44	1.43	2.50	2.52	2.51	43.21	42.79	43.00	44.88	47.12	46.00
SEm ±	0.006	0.004	0.003	0.011	0.009	0.007	0.158	0.161	0.113	0.29	0.31	0.21
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.83	0.89	0.60

Effect of bio-inoculants: Data (Table 4.26) further revealed that porosity of soil was not influenced significantly due to the inoculation of biofertilizer during both the years as well as on in pooled.

4.1.3.4 Water holding capacity

Effect of fertility levels: An examination of data presented in Table 4.26 revealed that fertility level of 100 % RDF significantly influenced the water holding capacity over 50 and 75 per cent RDF during both the years of experiment and on pooled basis. The significantly maximum water holding capacity was found with 100 per cent RDF over 50 per cent and 75 per cent RDF during both the years of experimentation and in pooled analysis. Application of resulted in 8.25 and 3.45 per cent increase in water holding capacity over 50 and 75 per cent RDF, respectively.

Effect of organic sources: It is apparent from the data given in Table 4.26 that water holding capacity improved significantly under the influence of different treatments of organic manures during both the years and in pooled basis. The significantly highest water holding capacity was observed with the application of vermicompost @ 5 t ha^{-1} over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during the both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} increased the mean water holding capacity significantly by 10.05, 4.07 and 7.18 per cent over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Further examination of data presented in Table 4.26 revealed that inoculation with biofertilizer significantly affect the water holding capacity during both the years and pooled basis. Dual inoculation of wheat seeds with *Azotobacter* + PSB significantly increased the mean water holding capacity by 2.66 per cent over no inoculation.

4.1.3.5 pH

Effect of fertility levels: The data presented in Table 4.27 showed that pH of soil was not influenced significantly due to the application of increasing levels of fertilizer during both the years as well as in pooled analysis.

Effect of organic sources: A perusal of data (Table 4.27) showed that pH of soil was not influenced significantly due to application of different treatments of organic manures during both the years as well as in pooled analysis.

Table 4.27 Effect of fertility levels, organic sources and bio-inoculants on pH, EC and organic carbon content in soil

Treatments	pH			EC (dSm^{-1})			Organic carbon (%)		
	2015-16	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
Fertility levels									
50% RDF	7.99	8.11	8.05	0.45	0.48	0.46	0.61	0.65	0.63
75% RDF	7.97	8.10	8.03	0.46	0.48	0.47	0.66	0.69	0.68
100% RDF	7.94	8.06	8.00	0.46	0.47	0.46	0.67	0.70	0.69
SEm ±	0.08	0.09	0.06	0.006	0.006	0.004	0.009	0.006	0.005
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	0.026	0.016	0.015
Organic sources									
FYM (5 t ha^{-1})	7.83	7.94	7.88	0.45	0.46	0.45	0.66	0.70	0.68
FYM (10 t ha^{-1})	7.91	8.06	7.99	0.45	0.47	0.46	0.68	0.72	0.70
VC (2.5 t ha^{-1})	8.02	8.13	8.08	0.46	0.48	0.47	0.61	0.65	0.63
VC (5 t ha^{-1})	8.10	8.21	8.16	0.46	0.49	0.47	0.63	0.67	0.65
SEm ±	0.10	0.10	0.07	0.007	0.007	0.005	0.010	0.006	0.006
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	0.030	0.018	0.017
Bio-inoculants									
Without inoculation	7.96	8.07	8.02	0.45	0.47	0.46	0.64	0.68	0.66
*Azotobacto*r + PSB	7.97	8.10	8.04	0.46	0.48	0.47	0.65	0.69	0.67
SEm ±	0.07	0.07	0.05	0.005	0.003	0.003	0.007	0.005	0.004
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Effect of bio-inoculants: Data (Table 4.27) further revealed that pH of soil was not influenced significantly due to the inoculation of biofertilizer during both the years as well as in pooled analysis.

4.1.3.6 EC

Effect of fertility levels: The data presented in Table 4.27 showed that EC of soil was not influenced significantly due to the application of increasing levels of fertilizer during both the years as well as in pooled analysis.

Effect of organic sources: A perusal of data (Table 4.27) showed that EC of soil was not influenced significantly due to application of different treatments of organic manures during both the years as well as in pooled analysis.

Effect of bio-inoculants: Data (Table 4.27) further revealed that EC of soil was not influenced significantly due to the inoculation of biofertilizer during both the years as well as in pooled basis.

4.1.3.7 Organic carbon

Effect of fertility levels: An examination of data presented in Table 4.27 revealed that increasing levels of fertilizer significantly influence the organic carbon content during both the years of experiment and pooled basis. The significantly maximum organic carbon content (0.66, 0.69 and 0.68 %) was found in 75 per cent RDF over 50 per cent RDF (0.61, 0.65 and 0.63 %) and statistically at par with 100 per cent RDF (0.67, 0.70 and 0.69 %) during both the years and in pooled. On pooled basis, application of 100 and 75 per cent RDF resulted in 8.73 and 7.14 per cent increase organic carbon content over 50 per cent RDF, respectively.

Effect of organic sources: Data on organic carbon content under the influence of different treatments of organic manure are presented in Table 4.27 revealed that the application of different organic manures differed significantly with respect to organic carbon of the soil during both the years and pooled basis. The significantly maximum organic carbon content (0.68, 0.72 and 0.70 %) recorded under the FYM @ 10 t ha^{-1} over 2.5 t vermicompost ha^{-1} (0.61, 0.65 and 0.63 %) and 5 t vermicompost ha^{-1} (0.63, 0.67 and 0.65 %) during both the years and in pooled. On pooled basis, application of FYM @10 t ha^{-1} resulted in 11.11 and 7.69 per cent increase in organic carbon content over 2.5 t vermicompost ha^{-1} and 5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data (Table 4.27) further revealed that organic carbon content of soil was not influenced significantly due to the inoculation of biofertilizer during both the years as well as in pooled analysis.

4.1.3.8 Available nitrogen

Effect of fertility levels: An assessment of data presented in Table 4.28 revealed that increasing levels of fertilizer significantly influenced the available nitrogen status of the soil during both the years of experimentation and in pooled. The significantly maximum available nitrogen in soil was found with the treatment 75 per cent RDF (323.6, 330.3 and 326.9 kg ha^{-1}) over 50 per cent RDF (309.4, 313.6 and 311.5 kg ha^{-1}) and statistically at par with 100 per cent RDF (330.8, 334.7 and 332.7 kg ha^{-1}) during both the years and in pooled analysis. On pooled basis, application of 100 and 75 per cent RDF resulted in 6.81 and 4.94 per cent increase available nitrogen in soil over 50 per cent RDF, respectively.

Effect of organic sources: It is evident from data presented in Table 4.28 revealed that the application of different organic manures were laid out significant affect on available nitrogen in soil during both the years and in pooled. The significantly maximum available nitrogen in soil was recorded (335.2, 347.6 and 341.4 kg ha^{-1}) with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} (303.9, 308.7 and 306.3 kg ha^{-1}) and 10 t FYM ha^{-1} (316.5, 310.2 and 313.3 kg ha^{-1}) but statistically at par with vermicompost @ 2.5 t ha^{-1} (329.6, 338.2 and 333.9 kg ha^{-1}) during both the years and in pooled analysis. On pooled basis, application of vermicompost @ 5 t ha^{-1} resulted in 11.46 and 8.97 per cent increase in available nitrogen in soil over 5 t FYM ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: A perusal of data presented in Table 4.28 showed that available nitrogen in soil affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum available nitrogen in soil (325.3, 331.1 and 328.2 kg ha^{-1}) was found with combined application of *Azotobacter* + PSB over without inoculation (317.3, 321.3 and 319.3 kg ha^{-1}) during both the years of study and in pooled basis. On pooled basis dual inoculation of wheat seed with *Azotobacter* + PSB resulted in 2.79 per cent increase in available nitrogen in soil over without inoculation, respectively.

4.1.3.9 Available phosphorus

Effect of fertility levels: It is evident from the data presented in Table 4.28 that increasing levels of fertilizer significantly influenced the available phosphorus status of the soil during both the years of experimentation and in pooled basis. The significantly maximum available phosphorus in soil was found with the treatment 75 per cent RDF (24.88, 26.52 and 25.70 kg ha^{-1}) over 50 per cent RDF (23.64, 24.97 and 24.30 kg ha^{-1}) and statistically at par with 100 per cent RDF (25.62, 26.98 and 26.30 kg ha^{-1}) during both the years and in pooled analysis. On pooled basis, application of 100 and 75 per cent RDF resulted in 8.05 and 6.21 per cent increase available phosphorus in soil over 50 per cent RDF, respectively.

Effect of organic sources: A perusal of data presented in Table 4.28 showed that the application of different organic manures were laid out significant affect on available phosphorus in soil during both the years and in pooled analysis. The significantly maximum available phosphorus in soil was recorded (26.11, 27.94 and 27.03 kg ha^{-1}) with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} (23.24, 24.69 and 23.97 kg ha^{-1}) and 10 t FYM ha^{-1} (24.06, 25.10 and 24.58 kg ha^{-1}) but statistically at par with vermicompost @ 2.5 t ha^{-1} (25.446, 26.89 and 26.16 kg ha^{-1}) during both the years and in pooled analysis. On pooled basis, application of vermicompost @ 5 t ha^{-1} resulted in 13.16 and 11.31 per cent increase in available phosphorus in soil over 5 t FYM ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: The data presented in Table 4.28 showed that available phosphorus in soil affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum available phosphorus in soil (25.13, 26.60 and 25.86 kg ha^{-1}) was found with combined application of *Azotobacter* + PSB over without inoculation (24.30, 25.71 and 25.01 kg ha^{-1}) during both the years of study and in pooled basis. On pooled basis dual inoculation of wheat seed with *Azotobacter* + PSB resulted in 3.46 per cent increase in available phosphorus in soil over without inoculation, respectively.

4.1.3.10 Available potassium

Effect of fertility levels: A critical examination of data presented in Table 4.28 indicated that increasing levels of fertilizer significantly influenced the available potassium status of the soil during both the years of experimentation and in pooled basis. The significantly maximum available potassium in soil was found with the treatment 75 per cent RDF (313.9, 318.5 and 316.2 kg ha^{-1}) over 50 per cent RDF

Table 4.28 Effect of fertility levels, organic sources and bio-inoculants on available N, P and K in soil after harvest of crop

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels									
50% RDF	309.4	313.6	311.5	23.64	24.97	24.30	295.2	297.1	296.1
75% RDF	323.6	330.3	326.9	24.88	26.52	25.70	313.9	318.5	316.2
100% RDF	330.8	334.7	332.7	25.62	26.98	26.30	317.7	321.9	319.8
SEm ±	3.3	4.0	2.6	0.32	0.32	0.23	2.6	2.6	1.8
CD (P = 0.05)	9.4	11.5	7.3	0.92	0.91	0.64	7.3	7.4	5.1
Organic sources									
FYM (5 t ha^{-1})	303.9	308.7	306.3	23.24	24.69	23.97	290.9	293.9	292.4
FYM (10 t ha^{-1})	316.5	310.2	313.3	24.06	25.10	24.58	302.3	302.5	302.4
VC (2.5 t ha^{-1})	329.6	338.2	333.9	25.44	26.89	26.16	318.8	324.4	321.6
VC (5 t ha^{-1})	335.2	347.6	341.4	26.11	27.94	27.03	323.7	329.2	326.5
SEm ±	3.8	4.7	3.0	0.37	0.37	0.29	3.0	3.0	2.1
CD (P = 0.05)	10.9	13.2	8.4	1.06	1.06	0.89	8.5	8.5	5.9
Bio-inoculants									
Without inoculation	317.3	321.3	319.3	24.30	25.71	25.01	304.6	308.5	306.6
*Azotobacto*r + PSB	325.3	331.1	328.2	25.13	26.60	25.86	313.2	316.5	314.9
SEm ±	2.7	3.3	2.1	0.26	0.26	0.19	2.1	2.1	1.5
CD (P = 0.05)	7.7	9.4	6.0	0.75	0.75	0.52	6.0	6.0	4.2

(295.2, 297.1 and 296.1 kg ha^{-1}) and statistically at par with 100 per cent RDF (317.7, 321.9 and 319.8 kg ha^{-1}) during both the years and in pooled analysis. On pooled basis, application of 100 and 75 per cent RDF resulted in 8.01 and 6.79 per cent increase available potassium in soil over 50 per cent RDF, respectively.

Effect of organic sources: The data presented in Table 4.28 showed that the application of different organic manures were laid out significant affect on available potassium in soil during both the years and in pooled analysis. The significantly maximum available potassium in soil was recorded (323.7, 329.2 and 326.5 kg ha^{-1}) with the application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} (290.9, 293.9 and 292.4 kg ha^{-1}) and 10 t FYM ha^{-1} (302.3, 302.5 and 302.4 kg ha^{-1}) but statistically at par with vermicompost @ 2.5 t ha^{-1} (318.8, 324.4 and 321.6 kg ha^{-1}) during both the years and in pooled analysis. On pooled basis, application of vermicompost @ 5 t ha^{-1} resulted in 11.66 and 7.97 per cent increase in available potassium in soil over 5 t FYM ha^{-1} and 10 t FYM ha^{-1}, respectively.

Effect of bio-inoculants: Data (Table 4.28) further showed that available potassium in soil affected due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum available potassium in soil (313.2, 316.5 and 314.9 kg ha^{-1}) was found with combined application of *Azotobacter* + PSB over without inoculation (304.6, 308.5 and 306.6 kg ha^{-1}) during both the years of study and in pooled basis. On pooled basis dual inoculation of wheat seed with *Azotobacter* + PSB resulted in 2.71 per cent increase in available potassium in soil over without inoculation, respectively.

4.1.3.11 Available iron

Effect of fertility levels: A perusal of data presented in Table 4.29 showed that increasing levels of fertilizer significantly influenced the available iron content of soil during both the years of experimentation and in pooled basis. The significantly maximum available iron in soil was found in 75 per cent RDF over 50 per cent RDF but remained at par with 100 per cent RDF during both the years and in pooled analysis. The per cent increase in mean available iron content in soil due to application of 100 and 75 per cent RDF were 6.95 and 5.30 per cent over 50 per cent RDF, respectively.

Effect of organic sources: An appraisal of data presented in Table 4.29 revealed that application of different organic manures significantly affect the available iron in soil during both the years and in pooled analysis. The significantly maximum available iron content in soil was recorded with 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and

2.5 t vermicompost ha^{-1} but statistically at par with 10 t FYM ha^{-1} during both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} resulted in 12.16 and 8.85 per cent increase in available iron in soil over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data (Table 4.29) further showed that available iron content in soil was not influenced significantly due to the inoculation of biofertilizer during both the years as well as in pooled analysis.

4.1.3.12 Available manganese

Effect of fertility levels: A perusal of data presented in Table 4.29 showed that increasing levels of fertilizer significantly influenced the available manganese content of soil during both the years of experimentation and in pooled basis. The significantly maximum available manganese in soil was found in 75 per cent RDF over 50 per cent RDF but remained at par with 100 per cent RDF during both the years and in pooled analysis. The per cent increase in mean available manganese content in soil due to application of 100 and 75 per cent RDF were 5.68 and 4.39 per cent over 50 per cent RDF, respectively.

Effect of organic sources: An appraisal of data presented in Table 4.29 revealed that application of different organic manures significantly affect the available manganese in soil during both the years and in pooled analysis. The significantly maximum available manganese content in soil was recorded with 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but statistically at par with 10 t FYM ha^{-1} during both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} resulted in 11.01 and 8.78 per cent increase in available manganese in soil over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data (Table 4.29) further showed that available manganese content in soil was not influenced significantly due to the inoculation of biofertilizer during both the years as well as in pooled analysis.

4.1.3.13 Available zinc

Effect of fertility levels: A critical examination of data presented in Table 4.29 showed that increasing levels of fertilizer significantly influenced the available zinc content of soil during both the years of experimentation and in pooled basis. The significantly maximum available zinc in soil was found in 75 per cent RDF over 50

Table 4.29 Effect of fertility levels, organic sources and bio-inoculants on available Fe, Mn, Zn and Cu in soil after harvest of crop

Treatments	Available Fe (mg kg^{-1})			Available Mn (mg kg^{-1})			Available Zn (mg kg^{-1})			Available Cu (mg kg^{-1})		
	2015-16	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
Fertility levels												
50% RDF	2.98	3.06	3.02	9.87	10.19	10.03	2.49	2.55	2.52	1.93	1.96	1.94
75% RDF	3.16	3.21	3.18	10.44	10.50	10.47	2.61	2.65	2.63	2.01	2.04	2.02
100% RDF	3.20	3.26	3.23	10.53	10.66	10.60	2.64	2.67	2.65	2.03	2.05	2.04
SEm ±	0.05	0.04	0.03	0.10	0.11	0.07	0.03	0.03	0.02	0.02	0.02	0.02
CD (P = 0.05)	0.13	0.12	0.09	0.28	0.32	0.21	0.08	0.08	0.06	0.07	0.06	0.05
Organic sources												
FYM (5 t ha^{-1})	2.93	2.99	2.96	9.77	9.86	9.82	2.48	2.47	2.47	1.92	1.90	1.91
FYM (10 t ha^{-1})	3.18	3.31	3.24	10.56	10.91	10.73	2.64	2.73	2.68	2.03	2.10	2.06
VC (2.5 t ha^{-1})	3.07	3.03	3.05	10.05	9.98	10.02	2.51	2.52	2.52	1.93	1.94	1.94
VC (5 t ha^{-1})	3.26	3.38	3.32	10.75	11.05	10.90	2.69	2.76	2.73	2.07	2.13	2.10
SEm ±	0.05	0.05	0.04	0.11	0.13	0.09	0.03	0.03	0.02	0.03	0.03	0.02
CD (P = 0.05)	0.15	0.14	0.10	0.32	0.37	0.24	0.09	0.09	0.06	0.08	0.07	0.05
Bio-inoculants												
Without inoculation	3.08	3.14	3.11	10.19	10.38	10.29	2.57	2.59	2.58	1.98	2.00	1.99
*Azotobacto*r + PSB	3.14	3.22	3.18	10.37	10.52	10.45	2.59	2.64	2.62	1.99	2.03	2.01
SEm ±	0.04	0.03	0.03	0.08	0.09	0.06	0.02	0.02	0.02	0.02	0.02	0.01
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

per cent RDF but remained at par with 100 per cent RDF during both the years and in pooled analysis. The per cent increase in mean available zinc content in soil due to application of 100 and 75 per cent RDF were 5.16 and 4.37 per cent over 50 per cent RDF, respectively.

Effect of organic sources: An examination of data (Table 4.29) showed that application of different organic manures significantly affect the available zinc in soil during both the years and in pooled analysis. The significantly maximum available zinc content in soil was recorded with 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but statistically at par with 10 t FYM ha^{-1} during both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} resulted in 10.53 and 8.33 per cent increase in available zinc in soil over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data (Table 4.29) further showed that available zinc content in soil was not influenced significantly due to the inoculation of biofertilizer during both the years as well as in pooled analysis.

4.1.3.14 Available copper

Effect of fertility levels: Data (Table 4.29) indicated that increasing levels of fertilizer significantly influenced the available copper content of soil during both the years of experimentation and in pooled basis. The significantly maximum available copper in soil was found in 75 per cent RDF over 50 per cent RDF but remained at par with 100 per cent RDF during both the years and in pooled analysis. The per cent increase in mean available copper content in soil due to application of 100 and 75 per cent RDF were 5.15 and 4.12 per cent over 50 per cent RDF, respectively.

Effect of organic sources: A perusal of data (Table 4.29) showed that application of different organic manures significantly affect the available copper in soil during both the years and in pooled analysis. The significantly maximum available copper content in soil was recorded with 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but statistically at par with 10 t FYM ha^{-1} during both the years and in pooled analysis. Application of vermicompost @ 5 t ha^{-1} resulted in 9.95 and 8.25 per cent increase in available copper in soil over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1}, respectively.

Effect of bio-inoculants: Data (Table 4.29) further showed that available copper content in soil was not influenced significantly due to the inoculation of biofertilizer during both the years as well as in pooled analysis.

4.1.4 Biological Properties of Soil

4.1.4.1 Dehydrogenase activity

Effect of fertility levels: It is evident from the data presented in Table 4.30 that increasing levels of fertilizer significantly influenced the dehydrogenase activity during both the years of experimentation and in pooled basis. The significantly maximum dehydrogenase activity was recorded as (5.66, 5.71 and 5.75 µg TPF g^{-1} soil) with application of 75 per cent RDF over 50 per cent RDF and statistically at par with 100 per cent RDF during both the years and in pooled.

Effect of organic sources: Data related to dehydrogenase activity under the influence of different treatments of organic manures are presented in Table 4.30 indicated that the application of different organic manures significantly increased the dehydrogenase activity during both the years and pooled basis. The significantly maximum dehydrogenase activity recorded as (5.77, 5.89 and 5.83 µg TPF g^{-1} soil) with the application of vermicompost @ 5 t ha^{-1} over both the levels FYM @ 10 t and 5 t ha^{-1} and remained at par with vermicompost @ 2.5 t ha^{-1} during both the years and in pooled analysis.

Effect of bio-inoculants: Data presented in Table 4.30 showed that dehydrogenase activity significantly affected due to inoculation of biofertilizer during both the years and pooled basis. The maximum dehydrogenase activity was recorded (5.67, 5.80 and 5.74 µg TPF g^{-1} soil) with the combined application of *Azotobacter* + PSB which was significantly superior over no inoculation during both the years and in pooled basis.

4.1.4.2 Bacteria population

Effect of fertility levels: An examination of data presented in Table 4.30 revealed that increasing levels of fertilizer significantly influenced the bacterial population during both the years of experiment and pooled basis. The significantly maximum bacterial population was recorded (25.84, 26.14 and 25.99 $x10^5$ CFU g^{-1}) with the application of 75 per cent RDF over 50 per cent RDF (24.27, 25.19 and 24.73 $x10^5$ CFU g^{-1}) and statistically at par with 100 per cent RDF (26.17, 26.46 and 26.32 $x10^5$

Table 4.30 Effect of fertility levels, organic sources and bio-inoculants on dehydrogenase activity, bacteria and fungi population in soil after harvest of crop

Treatments	Dehydrogenase activity (µg TPF g^{-1} soil)			Bacteria population (10^5 CFU g^{-1})			Fungi population (10^4 CFU g^{-1})		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels									
50% RDF	5.51	5.60	5.55	24.27	25.19	24.73	24.48	25.70	25.09
75% RDF	5.66	5.77	5.71	25.84	26.14	25.99	25.84	26.65	26.24
100% RDF	5.69	5.82	5.75	26.17	26.46	26.32	26.17	26.94	26.55
SEm ±	0.04	0.05	0.03	0.16	0.20	0.13	0.18	0.17	0.12
CD (P = 0.05)	0.12	0.15	0.10	0.47	0.56	0.36	0.51	0.47	0.34
Organic sources									
FYM (5 t ha^{-1})	5.47	5.54	5.50	24.26	24.82	24.54	24.26	25.07	24.67
FYM (10 t ha^{-1})	5.51	5.64	5.57	24.71	25.54	25.12	24.88	26.06	25.47
VC (2.5 t ha^{-1})	5.72	5.85	5.78	25.92	26.31	26.11	25.98	26.72	26.35
VC (5 t ha^{-1})	5.77	5.89	5.83	26.81	27.06	26.94	26.87	27.86	27.37
SEm ±	0.05	0.06	0.04	0.19	0.23	0.15	0.21	0.19	0.14
CD (P = 0.05)	0.14	0.18	0.11	0.54	0.65	0.42	0.59	0.55	0.39
Bio-inoculants									
Without inoculation	5.56	5.65	5.61	25.11	25.61	25.36	25.14	26.05	25.60
*Azotobacto*r + PSB	5.67	5.80	5.74	25.75	26.25	26.00	25.86	26.80	26.33
SEm ±	0.03	0.04	0.03	0.13	0.16	0.10	0.15	0.14	0.10
CD (P = 0.05)	0.10	0.13	0.08	0.38	0.46	0.29	0.41	0.39	0.28

CFU g^{-1}) during both the years and in pooled analysis. On pooled basis, application of 100 and 75 per cent RDF resulted in 6.43 and 5.10 per cent increase in bacterial population over 50 per cent RDF, respectively.

Effect of organic sources: Data on bacterial population under the influence of different treatments of organic manures are presented in Table 4.30 revealed that the application of different organic manures differed significantly with respect to bacterial population during both the years and pooled basis. The significantly maximum bacterial population recorded (26.81, 27.06 and 26.94 $x10^5$ CFU g^{-1}) with the application of vermicompost @ 5 t ha^{-1} over FYM @ 5 t ha^{-1} (24.26, 24.82 and 24.54 $x10^5$ CFU g^{-1}), FYM @ 10 t ha^{-1} (24.71, 25.54 and 25.12 $x10^5$ CFU g^{-1}) and vermicompost @ 2.5 t ha^{-1} (25.92, 26.31 and 26.11 $x10^5$ CFU g^{-1}) during both the years and in pooled basis.

Effect of bio-inoculants: An assessment of data presented in Table 4.30 showed that bacterial population affected due to inoculation of biofertilizers during both the years and pooled basis. The maximum bacterial population was recorded (25.75, 26.25 and 26.00 x 10^5 CFU g^{-1}) with the combined application of *Azotobacter* + PSB which was significantly superior over without inoculation (25.11, 25.61 and 25.36 x 10^5 CFU g^{-1}) during both the years and in pooled basis.

4.1.4.3 Fungi Population

Effect of fertility levels: An examination of data presented in Table 4.30 revealed that increasing levels of fertilizer significantly influenced the fungal population during both the years of experiment and pooled basis. The significantly maximum fungal population was recorded (25.84, 26.65 and 26.24 $x10^5$ CFU g^{-1}) when soil was enriched with 75 per cent RDF over 50 per cent RDF (24.48, 25.70 and 25.09 $x10^5$ CFU g^{-1}) and statistically at par with 100 per cent RDF (26.17, 26.94 and 26.55 $x10^5$ CFU g^{-1}) during both the years and in pooled. On pooled basis, application of 100 and 75 per cent RDF resulted in 5.82 and 4.58 per cent increase in fungal population over 50 per cent RDF, respectively.

Effect of organic sources: Data on fungal population under the influence of different treatment of organic manures are presented in Table 4.30 and showed that the application of different organic manures were found significant with respect to fungal population during both the years and pooled basis. The significantly maximum fungal population recorded (26.87, 27.86 and 27.37 x 10^5 CFU g^{-1}) with the application of vermicompost @ 5 t ha^{-1} over FYM @ 5 t ha^{-1} (24.26, 25.07 and 24.67 x 10^5 CFU g^{-1}), FYM @ 10 t ha^{-1} (24.88, 26.06 and 25.47 x 10^5 CFU g^{-1}) and vermicompost @ 2.5 t ha^{-1} (25.98, 26.72 and 26.35 x 10^5 CFU g^{-1}) during both the years and in pooled basis.

Effect of bio-inoculants: A perusal of data presented in Table 4.30 showed that fungal population influenced due to inoculation of biofertilizer during both the years and pooled basis. The significantly maximum fungal population was found with combined application of *Azotobacter* + PSB (25.86, 26.80 and 26.33 x 10^5 CFU g^{-1}) over no inoculation (25.14, 26.05 and 25.60 x 10^5 CFU g^{-1}) during both the years and in pooled basis.

4.1.5 Economics

Effect of fertility levels: Data presented in Table 4.31 showed that application of increasing level of fertilizers significantly increased the net returns and B:C ratio during both the years and in pooled analysis. Application of 75 percent RDF recorded significantly highest pooled mean net returns (₹ 63688) with B:C ratio of 2.28 closely followed by 100 per cent RDF (₹ 66419) with B:C ratio of 2.29. The pooled mean net returns was more by ₹ 12688 and 15419 under 75 % RDF and 100% RDF as compared to 50% RDF, respectively.

Effect of organic sources: The data in Table 4.31 revealed that significantly highest pooled mean net returns (₹ 64661) was found with the application of vermicompost @ 5 t ha^{-1} over other treatments however highest benefit cost ratio (2.38) were observed in vermicompost @ 2.5 t ha^{-1} over other treatments during both the years and pooled analysis respectively.

Effect of bio-inoculants: An evaluation of data in Table 4.31 showed that inoculation of seed with biofertilizer significantly increased the net returns and benefit cost ratio during both the years and in pooled analysis. The conjoint inoculation of *Azotobacter* + PSB obtained significantly maximum net returns (₹ 63711) and benefit cost ratio (2.28) over without inoculation during the years of study and in pooled analysis.

Table 4.31 Effect of fertility levels, organic sources and bio-inoculants on economics of wheat

Treatments	Net Return (₹ ha^{-1})			Benefit cost ratio		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Fertility levels						
50% RDF	50353	51648	51000	2.04	2.08	2.06
75% RDF	62289	65086	63688	2.25	2.31	2.28
100% RDF	64907	67930	66419	2.27	2.32	2.29
SEm ±	1427	1693	1107	0.03	0.03	0.02
CD (P = 0.05)	4062	4818	3109	0.07	0.09	0.06
Organic sources						
FYM (5 t ha^{-1})	55422	56942	56182	2.25	2.29	2.27
FYM (10 t ha^{-1})	59587	60739	60163	2.04	2.06	2.05
VC (2.5 t ha^{-1})	58457	62481	60469	2.33	2.43	2.38
VC (5 t ha^{-1})	63265	66057	64661	2.12	2.17	2.14
SEm ±	1648	1955	1278	0.03	0.04	0.02
CD (P = 0.05)	4690	5564	3590	0.09	0.11	0.07
Bio-inoculants						
Without inoculation	56116	57937	57027	2.13	2.16	2.14
*Azotobacto*r + PSB	62250	65172	63711	2.25	2.31	2.28
SEm ±	1165	1382	904	0.02	0.03	0.02
CD (P = 0.05)	3316	3934	2539	0.06	0.08	0.05

5. DISCUSSION

In course of presenting the result of the experiment entitled **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** significant variations were found in number of criteria studied for evaluation of treatments. In this chapter, an attempt has made to discuss variations found significant or those assuming a uniform trend to establish the cause and effects relationship as well as with existing evidences and literatures.

5.1 EFFECT OF FERTILITY LEVELS

5.1.1 Yield Attributes and Yield

Application of 75 per cent RDF to wheat significantly increased the number of effective tillers m^{-1} row length, number of grains $spike^{-1}$ and test weight (Table 4.1) as well as grain, straw and biological yield of wheat except harvest index (Table 4.2) during both the years as well as on basis of pooled analysis The positive effect of recommended application of fertilizers on yield attributing characters seems to be due to the cumulative effect on growth & vigour of plants. By virtue of increased supply of metabolites, there might have been significant improvement in biomass production with increasing fertilizer application. Increased growth components due to increased fertilizers might have provided stability in higher supply of photosynthates towards the sink (effective tillers, grain $spike^{-1}$ and test weight). Application of fertilizers might have supplied the adequate amount of plant nutrients that helped in the expansion of leaf area which may be accelerated the photosynthetic rate and ultimately the increased supply of carbohydrates to the plants. The improvements in yield attributing characters with recommended fertilizer application are in close conformity with Jat *et al*., 2014 and Borse, 2019). The significant increased in grain, straw and biological yield with increase in levels of fertilizer might be due to improvement in yield attributes. Application of NPK in balanced proportion and at proper time have greater impact on yield of wheat. The use of fertilizers in optimum manner can be achieved through maintaining the balanced fertilizer management for crop and ultimately for better yield. These results are supported by (Chauhan, 2014, Singh *et al*., 2018 and Maurya *et al*., 2019).

5.1.2 Nutrient Content and Uptake

Successive increase in fertilizer levels significantly increased the content and uptake of nutrients by grain and straw (Table 4.6 to 4.10, 4.14, 4.18 and 4.22 to 4.25). Application of 75% recommended fertilizer dose significantly increased the nutrient content in grain and straw however nutrient uptake was increased significantly up to 100% RDF. The significant increase in nutrient content is due to greater availability of nutrients in the soil applied through fertilizer addition. The uptake of nutrients is a function of biomass and nutrient content. This might be due to the improved nutritional environment in rhizosphere and in plant system, leading to the enhanced translocation of nutrients in plant parts. Goyal (2002) reported that recommended dose of fertilizer enhanced efficiency of nutrients, thus maintained synergistic interaction. The uptake of nutrients increased with progressive increase in supply of NPK to crop due to higher availability of these plant nutrients resulting higher biomass yield (Meena *et al*. 2018). Similar findings have also been reported by (Sharma *et al*., 2013 and Singh and Singh 2017).

5.1.3 Physico-chemical Properties of Soil

Soil nutrients *viz*. organic carbon, available N, P, and K are good indicators of soil qualities because of their favorable effect on physical and chemical properties of the soil. The significant improvement in physical and chemical properties of soil was observed by the addition of recommended fertilizer dose however bulk density, particle density, porosity, pH and EC remained unaffected due to different level of fertilizers (Table 4.26 and 4.27). Results revealed that application of increase in levels of fertilizer significantly enhance the water holding capacity of soil (Table 4.26). The increased water holding capacity with increase in levels of fertilizer in soil might be due to the enhanced rhizosphere in soil which ultimately enhanced the water holding capacity in soil (Bhatt *et al.,* 2017).

Organic carbon varied significantly under the various treatments applied in soil after harvest of wheat. Significantly the higher values of organic carbon was observed up to 75% RDF compared to 50% RDF (Table 4.27) clearly indicated the significant effect of fertilizers on build up of organic carbon. Use of fertilizers helps in increasing the soil organic carbon due to the higher biomass in terms of dry matter and differential rate of oxidation of the organic matter by microbes (Dhonde and Bhakare, 2008, Shukla *et al*., 2013 and Parewa *et al.,* 2014).

5.1.4 Available Nutrient in Soil after Harvest

Appropriate application of fertilizers is an important management practice to improve the soil fertility as well as productivity. Application of recommended dose of fertilizers from 50% to 100% significantly increased the available nutrient status in soil after harvest of wheat. It is summarized in table 4.28 and 4.29 that available nutrient content in soil increased significantly with increase in levels of fertilizer application but available nutrient status were found significantly higher up to 75% RDF which was at par with 100% RDF during both the years and in pooled basis. Significant increase in available nitrogen could be attributed to increase in activity of nitrogen fixing bacteria there by higher accumulation of nitrogen in soil (Parmer *et al*., 1998). Further, phosphorus status of soil increased with increase in level of fertilizer due to limited utilization of applied P by crop which resulted in buildup of soil phosphorus (Sharma *et al.,* 2013). The ample quantity of potassium could be attributed to the higher amount of potassium being added through murate of potash. These findings have been reported by (Gogoi, 2011 and Abbasi and Tahir, 2012).

5.1.5 Biological Properties of Soil

The dehydrogenase enzyme activity differed significantly among all the treatments (Table 4.30). The lower activities of these enzymes recorded in 50 percent RDF while significantly highest at 75 percent RDF during both the years and in pooled analysis. Masto *et al*., (2006) reported that dehydrogenase activity was mainly depends upon addition of nutrient amount. The increased enzymatic activity with the increase in levels of fertilizer application might be due to the fact that inorganic sources of nutrients stimulated the activity of micro-organisms for utilizing the native pool of soil organic carbon which act as a substrate for these enzymes (Bhatt *et al.,* 2017).

The microbial population (Table 4.30) showed higher soil bacterial population as compared to fungi in the rhizosphere after harvest of wheat crop. Result revealed that increase in levels of fertilizer from 50 to 100 percent RDF increased the bacterial and fungal population significantly in the rhizosphere. The increase in microbial population may be due to increase in levels of N, P and K which might have increased the root biomass, root exudates and ultimately provided the carbon and energy to soil microbes resulting into the multiplication of microbial population (Geetha Kumari and Shivashankar, 1991). These results are harmony with the finding of (Chand *et al*., 2010 and Parewa *et al.,* 2014).

5.1.6 Economics

The significantly highest net returns (₹ 62289, 65086 and 63688 ha^{-1}) and benefit cost ratio (2.25, 2.31 and 2.28) were recorded with 75 percent RDF which was at par with 100% RDF (Table 4.31). This trend of the net returns for crop depends upon cost of input and treatment effect on grain and straw yield. Similar results were also reported by (Jat *et al.,* 2014 and Chauhan, 2014).

5.2 EFFECT OF ORGANIC SOURCES

5.2.1 Yield attributes and Yield

Organic manures such as vermicompost and FYM are renewable and eco-friendly sources to achieve the sustainable productivity with minimum deterioration effect caused by chemical fertilizers on soil environment and soil health. It was often observed that the application of organic manures provide the significant increase in yield parameters *viz*., effective tillers $meter^{-1}$ row length, grains $spike^{-1}$ and test weight (Table 4.1). The application of 5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} observed significantly higher yield attributes compared to other organic manures. This might be ascribed to overall improvements in vigour and crop growth as already stated in preceding paragraphs. Since, FYM and vermicompost contains all essential plant nutrients, its incorporation in soil promotes rapid vegetative growth and tillering, thereby, increasing the sink size in terms of flowering, fruiting and seed setting. This is due to contribution in supplying the additional plant nutrients by treatments and increasing solubility of native soil nutrients. Another probable reason could be efficient and great partitioning of metabolites and adequate transformation of nutrients to developing plant structures. As a result, almost all yield attributes of crop were significantly influenced by vermicompost and FYM (Patel *et al*., 2014 and Singh *et al.,* 2018).

The beneficial effect of organic manures on yield attributes could be assumed due to enhanced supply of macro as well as micro nutrients during entire growing season. It might have attributed to higher manufacture of food in source and its subsequent partitioning in sink. The availability and supply of nutrients to formation ultimately increased the number of effective tillers, number of grains per spikes and test weight of wheat. Similar findings were observed by Behera *et al.* (2007), Verma *et al.* (2014) and Borse *et al.* (2019).

Significant increase in grain and straw yield was recorded with application of 5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} (Table 4.2). The significant increase in grain yield with application of manure might be due to their positive influence on maintaining balanced source–sink relationship which clearly evident from remarkable improvement in dry matter production, growth and yield characters like effective tillers, number of grains per spikes and test weight, which eventually resulted in increased grain yield. The increase in straw yield with the application of 5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} could be attributed to its direct influence on dry matter accumulation of each and every vegetative part and indirectly through the increased morphological parameters of growth. Since, biological yield is a function of both seed and straw yield representing the vegetative and reproduction growth of crop (Table 4.2). The profound influence of organic manuring on both these components of crop growth led to realization of higher biological yield. The results of the present investigation corroborate with the findings of Chopra *et al.* (2016), Singh and Singh (2017) and Kavinder *et al.* (2019).

5.2.2 Nutrient Content and Uptake

Organic manures worked as slow release fertilizer therefore they have more opportunity to uptake the nutrients continuously for longer period. The results in previous chapter showed a significant effect of organic manures on nutrients contents as well as its uptake by grain and straw. Application of 5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} significantly increase the N, P, K, Fe, Mn, Zn and Cu content and uptake by grain and straw during both the years and in pooled analysis (Table 4.6 to 4.10, 4.14, 4.18 and 4.22 to 4.25). The positive influence of organic manures on nitrogen, phosphorus, potassium, iron, manganese, zinc and copper content appears to be due to improved nutritional environment both in root zone and plant system. Increased availability of these nutrients in root zone coupled with increased metabolic activities at the cellular level probably increased the nutrient uptake and accumulation in the vegetative parts. Increased accumulation of these nutrients in vegetative parts possibly with improved metabolism led to higher translocation of nutrients to reproductive organs of the crop (Singh and Singh, 2017).

Increased grain and straw yield coupled with higher nutrient content in plant seemed to have increased uptake of these nutrients by the crop due to different treatments. The considerable increase in nutrient content and uptake by grain and straw could also be attributes to fact that the application of organic manures might have been stimulated plant growth, activity of soil micro-organisms resulted in higher fungal, bacterial and actinomycetes population and activity of soil enzymes (Knapp *et al.,* 2010). Significant influenced on these nutrient uptake by crop due to the application of organic manures increased the microbial respiration thus resulted in increased carbon content and plant nutrients mineralization rate in the soil (Powon *et al*., 2005). Higher nutrient uptake by the use of organic manures might have attributing the solubilization of native nutrient status, chelation of complex intermediate organic molecules produced during the decomposition of added organic manures as well as their mobilization and accumulation of different plant nutrients in various plant parts (Sharma *et al.,* 2013). These results are in closed agreement with findings of (Mitra *et al*., 2010 and Kumar and Pannu, 2012).

5.2.3 Physico-chemical Properties of Soil

The use of organic manures plays an important role in maintaining the soil health due to build up of soil organic matter in soil. Organic manures like FYM and vermicompost affect the physical and chemical properties of soil significantly. However, bulk density, particle density, porosity, pH and EC were not significantly influenced due to different sources of organic manures. Application of 5 t vermicompost ha^{-1} significantly improved the water holding capacity of the soil as compared to other treatments of organic manures (Table 4.26). This might be due to the fact that vermicompost has stable and low C: N ratio when added to soil, it maintains low bulk density and high moisture holding capacity for longer period compared to other organic sources under the study, which having relatively higher and less stable C: N ratio (Madhavi *et al.*, 2009 and Choudhary and Channappagouda, 2015).

Organic manures application improved the soil physical properties, aggregate stability, water holding capacity at both field capacity and wilting point, increase the soil aggregation and decrease the volume of micro pores while increase the macro pores, saturated hydraulic conductivity and water infiltration rate (Brar *et al.,* 2015). Despite of this, organic manures supply macro, micro and secondary nutrients to plants, improved the soil permeability to air and water and also increase the proportion of water stable aggregates in soil (Bhattacharyya *et al.,* 2007).

Besides improving the physical properties organic manures also affect chemical properties of soil. The soil organic carbon content increased significantly with different organic manures. Incorporation of FYM @ 10 t ha^{-1} significantly improved the soil organic carbon as compared to other treatments of manures (Table 4.27). The higher values of soil organic carbon with organic manures might be due to the direct addition, biological immobilization and continuous mineralization of FYM on surface layer of soil. Result of the investigation is close harmony with findings of (Ramesh *et al*., 2008, Bhardwaj *et al*., 2010 and Datt, *et al*., 2013).

5.2.4 Available Nutrients in Soil after Harvest

Use of organics is an important way of recycling the nutrients into soil. Application of organic manures significantly enhanced the available nutrients in soil. Application of 5 t vermicompost ha^{-1} recorded significantly higher values of available N, P and K in soil as compared to vermicompost @ 2.5 t ha^{-1} and FYM @ 10 t and 5 t ha^{-1} during both the years and pooled data basis (Table 4.28). Higher N, P, K content in soil under treatments of organic might be due to the continuous application of organic sources into soil. The superiority of vermicompost in increasing the available N status might be due to the increases population of beneficial micro-organisms such as N-fixers and increase in nitro-genase and urease enzyme activity (Gopalreddy, 1997 and Choudhary *et al*., 2013). These sources also enhance organic matter in soil which further improves physical condition of the soil, microbiological activities as well as increase the availability of plant nutrients (Kumar and Dhar, 2010 and Meena *et al.,* 2014). Singh *et al*., 2008 also confirmed the role of organic manures in releasing nitrogen and improving its availability in the soil. The application of 5 t vermicompost ha^{-1} resulted in highest available P and K content in soil during both the years and in pooled mean. Increase in P and K content in soil due to application of vermicompost produces various phenolic as well as aliphatic acids during decomposition which solubilize the phosphatase and other phosphate bearing minerals and thus lowers the phosphate fixation and thereby increase its availability (Choudhary *et al*., 2013 and Dotaniya *et al*., 2014). Higher availability of K might be due to the beneficial effect of vermicompost on reduction of potassium fixation and interaction with potassium clay to release K from the non-exchangeable fraction to the available pool (Ramesh *et al.,* 2008). The increase in available K content in soil increased with application of vermicompost may also be due to solubilising action of organic acids that produced during the decomposition and capacity to hold the K in available form (Vidyavathi *et al*., 2011and Choudhary *et al*., 2013).

Application of vermicompost @ 5 t ha^{-1} recorded significantly higher value of available Fe, Mn, Zn and Cu content in soil however, it remained at par with FYM @ 10 t ha^{-1}. This may be ascribed to the beneficial role of manures in mineralization of native as well as nutrients through fertilizer in addition of its own nutrient content which enhanced the available nutrient pool of the soil. As a matter of fact, all the available nutrients are not taken up by the plant and the rest remains in soil which improves available nutrient status of soil after harvest of crop. The favorable conditions for microbial as well as chemical activities due to addition of FYM and vermicompost integrated with other nutrients augmented the mineralization of nutrients and ultimately increased the available nutrients status of soil. These results are in agreement with those of Shukla *et al.* (2013) and Bhatt *et al*. (2017).

5.2.5 Biological Properties of Soil

All the biological reactions in the soil are catalyzed by various enzymes. The soil enzyme activities are believed to indicate the extent of specific processes in soil and in some cases it acts as an indicator of soil fertility. The dehydrogenase enzyme activity was strongly affected by organic manures. The activity of dehydrogenase was observed maximum with application of 5 t vermicompost ha^{-1} as compared to application of other organic manures (Table 4.30). Higher dehydrogenase enzyme activities in soils amended with organic sources were not only due to the large microbial biomass but also of higher amount of endo and greater enzyme production by microbial biomass. The activity of dehydrogenase enzyme was closely related to the soil organic matter and microbial biomass under the different agro-ecosystems. Among the all organic sources evaluated incorporation of vermicompost followed by FYM performed better for improving biochemical properties (Goyal *et al*., 1993, Ramesh *et al*., 2008 and Khursheed *et al*., 2012).

The composition and density of microbial population is an important aspect of quality of soil organic matter because it provides an indication of soil ability to store and recycle nutrients and energy. The application of different organic manures increased the population of bacteria and fungi significantly. Addition of vermicompost enhanced the microbial population significantly as compared to FYM. It might have also enhanced the microbial counts in soil due to addition of carbon and changes in physico-chemical properties of soil (Meena *et al*., 2015). Increase in microbial population with application of organic manures might be due to stimulated growth and activities of soil micro-organism. The population of micro-organism increased due to lower C: N ratio and high in total N and P content of vermicompost than other manures (Goyal *et al.,* 1993, Upadhyay *et al*., 2011). Similar findings also reported by (Knapp *et al.,* 2010 and Meena *et al.,* 2015).

5.2.6 Economics

The results showed that application of vermicompost 5 t ha^{-1} obtained significantly higher net returns of ₹ 63265, 66057 and 64661 ha^{-1} and benefit cost ratio (2.12, 2.17 and 2.14) than other organic manures treatment during both the years and in pooled analysis (Table 4.31). This trend in net return is mainly due to higher cost and treatment effect on grain and straw yield of wheat. Similar findings were given by (Channabasanagowda *et al*., 2008, Choudhary *et al*., 2013 and Baishya *et al.,* 2015).

5.3 EFFECT OF BIO-INOCULANTS

5.3.1 Yield attributes and Yield

The addition of biofertilizers, *i.e.* live microorganisms (bacteria and fungi) is known to improve the plant growth and productivity. The results showed that dual inoculation of *Azotobacter* + PSB significantly increased the yield attributes and yield of wheat during both years and in pooled mean. Biofertilizers significantly increased the number of tillers meter^{-1} row length, number of grains spike^{-1}, test weight, grain, straw and biological yield of wheat (Table 4.1 and 4.2) during both the years and in pooled basis.

The biofertilizer application significantly improved grain and straw yield of wheat was reported by (Malik *et al.,* 2009). Biofertilizers play an important role in meeting out the nutrient requirement of crops and enhance soil fertility as well as crop productivity by fixing atmospheric nitrogen and mobilizing sparingly soluble phosphate. *Azotobacter* and *phospho bacteria* produce the growth hormones *viz.*, Indole acetic acid and Gibberellins. These hormones stimulate root growth and development of plant. The use of growth stimulating inoculants helps to accelerate the uptake of plant nutrients applied from chemical fertilizers by increasing the root growth. The significant increase in straw yield under dual inoculation of *Azotobacter* + PSB might to be due to their direct effect in improving the biomass production and indirect effect might be on account of increase in morphological parameters, however, when N- fixers and PSB were used together there was significant additive effect (Kaushik *et al.,* 2012 and Ram and Mir, 2006).

5.3.2 Nutrient Content and Uptake

Application of biofertilizer to crop improves the absorption availability of many plant nutrients. Results showed that inoculation of biofertilizers significantly influenced the nutrient content and uptake by grain and straw (Table 4.6 to 4.10, 4.14, 4.18 and 4.22 to 4.25). Abbasi *et al.,* 2011 obtained that the uptake of N and P by shoots of plant was increased by three fold, while K uptake was increased by 58% by the inoculation of biofertilizers. The nutrient content and uptake by crop significantly increased with inoculation of *Azotobactor* and PSB prior to sowing because *Azotobactor* can be ascribed to increased specific activities of iso citric and malic dehydrogenase, the source of electrons for nitrogen fixation creating a better nutritional environment (Kurtz and Larue, 1975) and PSB solubilize the native and applied phosphorus (Singh *et al*, 2012a). These findings are in confirmation with findings of (Mahmoud, 2006, Marozsan, *et al*., 2009, Suke *et al.,* 2011 and Singh *et al*., 2012a).

Dual inoculation of *Azotobactor* + PSB significantly increased the content and uptake of nutrient under study which may be attributed to fixation of nitrogen and better root growth due to increased availability of phosphorus by PSB besides secretion of growth promoting substances especially by *Azotobactor* and *Azospirillum* (Totawat *et al*., 2000). These findings have also reported by (Dadarwal *et al.,* 2009 and Balai *et al.,* 2011 and Singh *et al*., 2012a).

5.3.3 Physico-chemical Properties of Soil

Application of biofertilizers to arable soil influenced the physical and chemical properties as well as water holding capacity of soil. Inoculation of *Azotobactor* + PSB resulted in higher water holding capacity of soil after harvest of the crop (Table 4.26). Bulk density, particle density, porosity as well as pH, EC and organic carbon content in soil were not influenced due to biofertilizers (Table 4.27). Wu *et al.,* 2005 resulted that biofertilizers are products containing arbuscular mycorhizal fungi, N-fixers (*Azotobactor chroococcum*), P-solubilizers (*Bacillus megaterium*) and K solubilizers (*Bacillus mucilaginous*) which improve the chemical properties of soil. Biofertilizer also improve the soil texture, structure, nutrient supply and useful micro-organism which enhances the root biomass and ultimately organic carbon content in soil (Sharma, 2011 and Parewa *et al*., 2014).

5.3.4 Available Nutrient in Soil after Harvest

Biofertilizers are very well known to play number of vital roles in improving the soil fertility. As they are living cells of different types of micro-organism either bacteria, algae and fungi etc which have ability to mobilize nutritionally important elements from non usable forms. Results described in preceding chapter showed that inoculation of biofertilizer significantly improved the available N, P and K content in soil (Table 4.28). The dual inoculation of *Azotobacter* + PSB significantly improved the available N, P and K content in soil after harvest of wheat crop. PSB secretes some organic acids which can solubilize phosphate from fixed forms to plant available forms whereas *Azotobacter* can convert the atmospheric N into available form in the soil. But the increase in yield by inoculation of biofertilizers may not be solely due to N_2-fixation or P-solubilization because of several other factors such as release of growth promoting substances, control of plant pathogens and proliferation of beneficial organisms in rhizosphere. These results are corroborating with the findings of (Mathews *et al.,* 2006, Singh *et al.,* 2008a and Parewa *et al.,* 2014). Micronutrients like Fe, Mn, Zn and Cu remained unaffected due to application of biofertilizers (Table 4.29).

5.3.5 Biological Properties of Soil

Microbial diversity and their richness in soil are key inputs to understanding the role, function and significance of micro-organisms in plant nutrient supply. Biofertilizers have positive and significant impact on soil biological properties. Dual inoculation of biofertilizer significantly improved the dehydrogenase activity and microbial population in soil (Table 4.30). The dehydrogenase activity was an index of microbial activity as it refers to group of mostly endo cellular enzymes which catalyze oxidation of soil organic matter (Pascual *et al.,* 1998). The increased enzyme activity and population of microbes in soil may be due to the improvement in the porosity and more availability of nutrients to plant as well as better establishment of inoculated microorganism which stimulates the indigenous micro-organisms (Shinde and Bangar, 2003). These similar findings were given by (Parewa *et al*., 2014 and Singh *et al.,* 2015). Sushila (1998) also reported the increase in microbial population in rhizosphere with *Azospirillum* and *Azotobacter* inoculations in wheat. Similar finding was also given by (Ram and Mir, 2006).

5.3.6 Economics

Inoculation of biofertilizer significantly affects the net return and benefit cost ratio of wheat. The highest pooled mean net returns (₹ 63711 ha^{-1}) and benefit cost ratio (2.28) was obtained with dual inoculation of *Azotobacter* + PSB as compared to without inoculation (Table 4.31). The use of efficient strains of biofertilizers are environment friendly and low cost input that have an important role in improving the nutrient supply to crops and also reducing the cost of production (Kumar, 2013). These results are corroborate with the findings of (Galal *et al.,* 2001, Ram and Mir, 2006).

6. SUMMARY AND CONCLUSION

The results of experiment entitled **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** conducted at Agronomy Farm, Rajasthan College of Agriculture, Udaipur during *rabi* season for two consecutive years of 2015-16 and 2016-17 presented and discussed in the preceding chapters are being summarized and concluded in this chapter below :

6.1 EFFECT OF FERTILITY LEVELS

6.1.1 Enrichment of soil with 75 per cent RDF significantly increased the effective tillers m^{-1} row length (103.7, 106.2 and 105), number of grains $spike^{-1}$ (41.5, 42.5 and 42.0) and test weight (38.7, 40.7 and 39.7) of wheat over 50 per cent RDF and statistically at par with 100 per cent RDF during both the years and in pooled analysis.

6.1.2 Application of 75 per cent RDF being at par with 100 per cent RDF significantly increased the grain (45.1, 46.2 and 45.6 q ha^{-1}), straw (89.9, 92.3 and 91.1q ha^{-1}) and biological yield (135.0, 138.5 and 136.7 q ha^{-1}) over 50 per cent RDF during both the years and in pooled analysis.

6.1.3 Crop fertilized with 75 per cent RDF significantly increased the N, P, K content in grain and straw and protein content in grain over 50 per cent RDF but remained at par with 100 per cent RDF during both the years and in pooled analysis.

6.1.4 Application of 75 per cent RDF significantly increased the Fe, Mn, Zn and Cu content in grain and straw over 50 per cent RDF and at par with 100 per cent RDF during both the years and in pooled analysis.

6.1.5 Increasing levels of fertility up to 100 per cent RDF significantly increased the N, P, K, Fe, Mn, Zn and Cu uptake both in grain and straw as well as total uptake over 50 and 75 per cent RDF during both the years and in pooled mean basis.

6.1.6 Application of 100 per cent RDF significantly increased the water holding capacity of soil while organic carbon, available N, P, K, Fe, Mn, Zn and Cu content of soil increased up to 75 per cent RDF over 50 per cent RDF but at par with 100 per cent RDF during both the years and in pooled analysis.

6.1.7 Application of 75 per cent RDF significantly increased the dehydrogenase activity, bacteria and fungi population of soil over 50 per cent RDF while at par with 100 per cent RDF during both the years and in pooled analysis.

6.1.8 Application of 75 percent RDF recorded significantly highest pooled mean net returns (₹ 63688) with B:C ratio of 2.28 closely followed by 100 per cent RDF (₹ 66419) with B:C ratio of 2.29.

6.2 EFFECT OF ORGANIC SOURCES

6.2.1 Application of 5 t vermicompost ha^{-1} significantly increased the effective tillers m^{-1} row length, number of grains $spike^{-1}$ and test weight of wheat over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but remained at par with 10 t FYM ha^{-1} during both the years of study as well as on pooled basis.

6.2.2 Application of 5 t vermicompost ha^{-1} significantly increased the grain, straw and biological yield of wheat over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but remained at par with 10 t FYM ha^{-1} during both the years of study as well as on pooled basis.

6.2.3 Application of 5 t vermicompost ha^{-1} significantly increased the N, P, K content in grain and straw and protein content in grain over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but remained at par with 10 t FYM ha^{-1} during both the years and in pooled analysis.

6.2.4 The Fe, Mn, Zn and Cu content in grain and straw significantly improved with application of 5 t vermicompost ha^{-1} over 5 t FYM ha^{-1} and 2.5 t vermicompost ha^{-1} but remained at par with 10 t FYM ha^{-1} during both the years and in pooled analysis.

6.2.5 Application of 5 t vermicompost ha^{-1} significantly increased the N, P, K, Fe, Mn, Zn and Cu uptake both in grain and straw as well as total uptake over 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} during both the years and in pooled mean basis.

6.2.6 Application of 5 t vermicompost ha^{-1} significantly increased the water holding capacity of soil while organic carbon content in soil increased with 10 t FYM ha^{-1} however, available N, P, K, Fe, Mn, Zn and Cu content of soil increased with 5 t vermicompost ha^{-1} during both the years and in pooled analysis.

6.2.7 Application of 5t vermicompost ha^{-1} significantly increased the dehydrogenase activity, bacteria and fungi population of soil over 10 t and 5 t FYM ha^{-1} and at par with 2.5 t vermicompost ha^{-1} during both the years and in pooled analysis.

6.2.8 The highest pooled mean net returns (₹ 64661) was found with the application of vermicompost @ 5 t ha^{-1} over other treatments however highest benefit cost ratio (2.38) were observed in vermicompost @ 2.5 t ha^{-1} over other treatments during both the years and pooled analysis respectively.

6.3 EFFECT OF BIO-INOCULANTS

6.3.1 Inoculations of seed with *Azotobacter* + PSB significantly increased the effective tillers m^{-1} row length, number of grains $spike^{-1}$ and test weight of wheat crop during both the years and in pooled analysis.

6.3.2 Inoculations of seed with *Azotobacter* + PSB significantly increased the grain, straw and biological yield of wheat during both the years and in pooled analysis.

6.3.3 Inoculations of seed with *Azotobacter* + PSB significantly increased the N, P, K, Fe, Mn, Zn and Cu content as well as their uptake by grain and straw and protein content in grain over without inoculation during both the years and in pooled analysis.

6.3.4 Inoculations of seed with *Azotobacter* + PSB significantly increased the water holding capacity as well as available N, P and K content in soil over without inoculation during both the years and in pooled analysis.

6.3.5 Inoculation of seed with *Azotobacter* + PSB significantly increased the dehydrogenase activity, bacteria and fungi population of soil over without inoculation during both the years and in pooled analysis.

6.3.6 The conjoint inoculation of *Azotobacter* + PSB obtained significantly maximum net returns (₹ 63711) and benefit cost ratio (2.28) over without inoculation during the years of study and in pooled analysis.

6.4 INTERACTION EFFECTS

6.4.1 Combined use of vermicompost @ 5 t ha^{-1} along with 75% RDF significantly increased the grain, straw and biological yields of crop over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF.

6.4.2 Combined use of vermicompost @ 5 t ha^{-1} along with 75% RDF significantly increased the nitrogen, phosphorus and potassium uptake by grain, straw and total uptake over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF.

CONCLUSION

On the basis of two year study, it is concluded that 75% RDF (RDF-90 kg N, 45 kg P and 30 kg K) + 5 t vermicompost + *Azotobacter* + PSB (Treatment-$F_2O_4B_2$) in wheat should be applied for better nutrient management, physico- chemical properties and microbial activates of soil throughout the *rabi* season for obtaining higher yields and better economic returns however highest benefit cost ratio (2.38) was observed with application of vermicompost @ 2.5 t ha^{-1} (Treatment – $F_2O_3F_2$) over the other treatments.

LITERATURE CITED

A.O.A.C. 1960. Official methods of analysis. 9th edition Association of Official Agricultural Chemists, Washington DC. Pp-119.

Aatif, M., Khan, H., Anjum, M.A., Ali, N. and Hamid, M. 2017. Effect of Farm yard manure and phosphorus levels on yield and yield components of wheat. *International Journal of Environmental Science and Natural Resources*, **2**(4): 133-137.

Abbasi, M.K. and Tahir, M.M. 2012. Economizing nitrogen fertilizer in wheat through combinations with organic manures in Kashmir, Pakistan. *Agronomy Journal*, **104**(1):169-177.

Abraham, T. and Lal, R.B. 2004. Effect of integrated nutrient management on productivity of wheat and soil fertility in a legume based cropping system. *Indian Journal of Agricultural Research*, **38**(3): 178-183.

Afzal, A., Ashraf, M., Saeed, A. Asad, and Farooq, M. 2005. Effect of phosphate solubilizing microorganisms on phosphorus uptake, yield and yield traits of wheat (*Triticum aestivum* L.) in rainfed area. *International Journal of Agriculture and Biology*, **7**: 207-209.

Agrawal, S.B., Singh, A. and Dwivedi, D. 2003. Effect of vermicompost, farm yard manure and chemical fertilizers on growth and yield of wheat (*Triticum Aestivum* L.). *Plant Archives*, **3**(1): 9-14.

Alam, M.S., Mishra, A.K., Singh, K., Singh, K.S. and David, A. 2014. Response of sulphur and FYM on soil physico-chemical properties and growth, yield and quality of mustard (*Brassica nigra* L.). *Journal of Agriculture Physics*, **14**(2):156-160.

Anonymous 2018-19. Vital Agriculture Statistics. Directorate of Agriculture, Jaipur, Rajasthan.

Anonymous 2019-20. Economic survey of India, Ministry of Finance (Economic Division) GOI, New Delhi.

Arif, M., Tasneem, M., Bashir, F., Yaseen,G., and Iqbal, R.M. 2014. Effect of integrated use of organic manures and inorganic fertilizers on yield and yield components of rice. *Journal of Agricultural Research*, **52**(2) 197-206.

Baber, S. and Dongale, J.H. 2011. Effect of integrated use of inorganic and organic manure on yield and monetary returns of mustard-cowpea-rice cropping sequence in lateritic soils of Konkan. *Journal of Soils and Crops* **21**(2): 225-233.

Bahadur, L., Tiwari, D.D, Mishra, J. and Gupta, B.R. 2013. Evaluation of integrated nutrient management options in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system in reclaimed sodic land. *Indian Journal of Agronomy,* **58** (2): 137-145.

Bairwa, V., Dahiya, R., Kumar, P. and Phogat, V.K. 2013. Effect of long term integrated nutrient management on soil properties, soil fertility, nutrient uptake and crop yields under pearl millet-wheat cropping system. *Research on Crops*; **14**(3):762-768.

Baishya, L.K., Rathore, S.S., Singh, D., Sarkar, D. and Deka, B.C. 2015. Effect of integrated nutrient management on rice productivity, profitability and soil fertility. *Annals of Plant and Soil Research,* **17**(1): 86-90.

Balai, M. L., Verma, A., Nepalia, V. and Kanthaliye, P. C. 2011. Productivity and quality of maize (*Zea mays*) as influenced by integrated nutrient management under continuous cropping and fertilization. *The Indian Journal of agricultural Sciences*, **81**: 374-76.

Bandyopadhyay, K.K. Ghosh, P.K. Hati, K.M. and Misra, A.K. 2009. Efficient utilization of limited available water in wheat through proper irrigation scheduling and integrated nutrient management under different cropping system in a Vertisols. *Journal of the Indian Society of Soil Science*, **57**(2): 121-128.

Behera, U.K. 2009. Organic manuring for soil biological health and productivity of a wheat-soybean cropping system in the Vertisols of central India. *Crop & Pasture Science*; **60**(4): 382-393.

Behera, U.K., Pradhan, S. and Sharma, A.R. 2007. Effect of integrated nutrient management practices on productivity of durum wheat (*Triticum durum*) in the Vertisols of central India. *Annals of Plant and Soil Research*, **1**: 21-24.

Bevacqua R. F. and Mellano V. 2013. Compost science and utilization. *Spring* **13**: 34-37.

Bhardwaj, S.K., Sharma, I.P. and Sharma, S.D. 2010. Effect of integrated nutrient management on soil fertility, yield and quality of tomato and french bean crops in the mid Himalayas. *Journal of the Indian Society of Soil Science*, **54**(4): 464-466.

Bhatt, M.K. Labanya, R., Joshi, H.C., Pareek, N., Chandra, R. and Raverkar, K.P. 2017. Long-term effects of inorganic fertilizers and FYM on soil chemical properties and yield of wheat under rice-wheat cropping system. *ENVIS Bulletin Himalayan Ecology*, **25**: 28-35.

Bhattacharyya R., Chandra S., Singh R.D., Kundu S., Srivastva A.K. and Gupta H.S. 2007. Longterm farmyard manure application effects on properties of a silty clay loam soil under irrigated wheat–soybean rotation. *Soil Tillage Research,* **94**: 386-396.

Black, C.A. 1965. *Methods of soil analysis*. Pub. American Society of Agronomy, Madison, Wisconsis, USA.

Bodruzzaman, M., Meisner, C.A., Sadat, M.A. and Hussain, M.I. 2010. Long term effects of applied organic manures and inorganic fertilizers on yield and soil fertility in a wheat-rice cropping system. *Proceedings of the 19th World Congress of Soil Science: Soil Solutions for a Changing World, Brisbane, Australia, 1-6 Aug, 2010. Symposium on Dynamics of organic material in soils* **14:** 143.

Borse, D.K., Usadadia, V.P. and Thorave, D.S. 2019. Nutrient management in wheat (*Triticum aestivum* L.) under partially reclaimed coastal salt affected soil of south Gujarat. *International Journal of Current Microbiology and Applied Sciences,* **8** (5): 1590-1599.

Brar, B.S., Singh, J., Singh, G. and Kaur, G. 2015. Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. *Agronomy*, **5**: 220-238.

Casida, I.E., Klein, D.A. and Santore, T. 1964. Measurement of dehydrogenase activity by incubating the soil with TTC method. *Soil Science*, **98**: 373.

Chand, S., Somani, L.L. and Bhandari, S.C. 2010. Effect of fertilizer, farmyard manure (FYM) and biofertilizer on the population of *Azotobacter* and phosphate solubilising bacteria (PSB) in the soil. *Journal of the Indian Society of Soil Science*, **58**(4): 460-463.

Channabasanagowda, Patil, N.K., Patil, B.N., Awaknavar, J.S., Ninganur, B.T. and Hunje, R. 2008. Effect of organic manures on growth, seed yield and quality of wheat. *Karnataka Journal of Agriculture Science*, **21**(3): 366-368.

Chauhan, D.S., Sharma, R.K., Tripathi, S.C., Kharub, A.S. and Chhokar, R.S. 2011a. News paradigm in tillage technology for wheat production. Research Bulletin No. 8, DWR, Karnal, **16**.

Chauhan, P.K., Singh, V., Dhatwalia, V.K. and Abhishek, B. 2011. Physico-chemical and microbial activity of soil under conventional and organic agricultural systems. *Journal of Chemical and Pharmaceutical Research*, **3**(3): 799-804.

Chauhan, R.S. 2014. Effect of fertility and weed management on yield, nutrient uptake and economics of wheat. *Annals of Plant and Soil Research* **16**(4): 304-307.

Chesti, M.H., Kohli, A. and Sharma, A.K. 2013. Effect of integrated nutrient management on yield of and nutrient uptake by wheat (*Triticum aestivum*) and soil properties under intermediate zone of Jammu and Kashmir. *Journal of the Indian Society of Soil Science*, **61**(1): 1-6.

Chopra, R., Sharma, M., Sharma, S.K., Nepalia, V., Jain, H.K. and Singh, A. 2016. Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.) in Haplustepts. *International Journal of Science and Nature*, **7**(3): 622-628.

Choudhary, A.K., Thakur, R.C. and Kumar, N. 2008. Effect of integrated nutrient management on soil physical and hydraulic properties in rice-wheat crop sequence in N-W Himalayas. *Indian Journal of Soil Conservation*, **36** (2): 97-104.

Choudhary, S., Yadav, L.R., Yadav, S.S., Sharma, O.P. and Keshwa, G.L. 2013. Integrated use of fertilizers and manures with foliar application of iron in barley (*Hordeum vulgare*). *Indian Journal of Agronomy*, **58**(3): 363-367.

Choudhary, V.V. and Channappagouda, B.B. 2015. Effect of organics on morpho-physiological traits and grain yield of maize (*Zea mays* L.). *The Bioscan*, **10**(1): 339-341.

Dadarwal, R. S., Jain, N. K. and Singh, D. 2009. Integrated nutrient management in baby corn (Zea mays). *The Indian Journal of Agricultural Sciences,* **79**: 1023-1025.

Das, B.B. and Dkhar, M.S. 2012. Organic amendment effects on microbial population and microbial biomass carbon in the rhizosphere soil of soybean. *Communications in Soil Science and Plant Analysis*; **43**(14): 1938-1948.

Datt, N., Dubey, Y.P. and Chaudhary, R. 2013. Studies on impact of organic, inorganic and integrated use of nutrients on symbiotic parameters, yield, quality of French-bean (*Phaseolus vulgaris* L.) vis-à-vis soil properties of an acid Alfisol. *African Journal of Agricultural Research*, **8**(22): 2645-2654.

Davari, M.R., Sharma, S.N. and Mirzakhani, M. 2012. Effect of combinations of organic materials and biofertilizers on productivity, grain quality, nutrient uptake and economics in organic farming of wheat. *Journal of Organic Systems*, **7**(2): 26-35.

Devi, K.N., Singh, M.S., Singh, N.G., and Athokpam, H.S. 2011. Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.). *Journal of Crop and Weed,* **7**(2): 23-27.

Dhaka, B.R., Chawla, N. and Pathan, A.R.K. 2012. Integrated nutrient management on performance of wheat (*Triticum aestivum* L.). *Annals of Agricultural Research,* **33** (4): 214-219.

Dikshit, P.R. and Khatik, S.K. 2002. Influence of organic manures in combination with chemical fertilizers on production quality and economic feasibility of Jabalpur. *Legume Research* **25**(1): 53-56.

Dhonde, M.B., and Bhakare, B.D. 2008. Influence of integrated nutrient management on soil properties of vertisols under sorghum-wheat cropping sequence. *Journal Research Acharya N. G. Ranga Agricultural University,* **36**(2 & 3): 1-8.

Donald, C.M. and Hamblin, J. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Advances in Agronomy,* **28**: 361-405.

Dotaniya, M.L., Datta, S.C., Biswas, D.R., Meena, H.M. and Kumar, K. 2014. Production of oxalic acid as influenced by the application of organic residue and its effect on phosphorus uptake by wheat (*Triticum aestivum* L.) in an Inceptisol of north India. *National Academy Science Letters*, **37**(5): 401-405.

Dubey, S., Chandra, H. and Singh, S.G. 2010. Grain yield of wheat as effect by growth promoting bacteria. *Advances in Plant Sciences*, **23**(2): 543-544.

Edwards, C.A. and I. Burrows, 2010. The potential of earthworm composts as plant growth media. In: Earthworms in environmental and waste management, Edwards, C.A. and S.P.B. Newhauser (Eds.) Academic Publication.

Fisher, R.A. and Yates, F. 1963. Statistical tables. Oliver and Boyd, Edinburgh, London.

Galal, Y. G., El-Gandaour, J. A. and El-Akel, F. A. 2001. Stimulation of wheat growth and N fixation through Azospirillum and Rhizobium inoculation. A field trial with 15N techniques. *Plant Nutrition Food Security and Sustainability of Agro-ecosystems,* 666-667.

Geetha Kumari, V.L. and Shivashankar, K. 1991. Studies on organic amendment and CO_2 enrichment in ragi/soybean intercropping systems. *Indian Journal of Agronomy*, **36**:202-206.

Ghanshyam, Kumar, R. and Jat, R.K. 2010. Productivity and soil fertility as affected by organic manures and inorganic fertilizers in green gram (*Vigna radiata*)-wheat (*Triticum aestivum*) system. *Indian Journal of Agronomy* **55**(1): 16-21.

Gogoi, B. 2011. Soil properties and nutrient availability as affected by INM after rainfed cropping sequence. *Indian Journal of Agricultural Research*, **45**: 346-349.

Gopalreddy, B. 1997. Soil health under integrated nutrient management in maize soybean cropping system. *Ph.D Thesis*, Acharya N.G. Ranga Agril. Univ., Hyderabad (India).

Goyal , S., Mishra, M.M., Dhankar,. S.S. kapoor, K.K. and Batra, R. 1993. Microbial biomass turnover and enzyme activities following the application of farmyard manure to field soils with and without previous long term applications. *Biology and fertility of soils*, **15**: 60-64.

Goyal, J.P. 2002. Integrated nutrient management in maize- wheat cropping sequence. *Ph.D Thesis* Department of Agricultural Chemistry and Soil Science, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (India).

Hemalatha, S. and Chellamuthu, S. 2013. Impacts of Long Term Fertilization on Soil Nutritional Quality Under Finger Millet:Maize Cropping Sequence. *Journal of Environmental Research and Development*, **7**(4A): 1571-1576.

Ingle, S.S., Jadhao, S.D., Kharche, V.K., Sonune, B.A. and Mali, D.V. 2014. Soil biological properties as influenced by long-term manuring and fertilization under sorghum (*Sorghum bicolor*)-wheat (*Triticum aestivum*) sequence in Vertisols. *Indian Journal of Agricultural Sciences,* **84**(4): 452-457.

Jackson, M.L. 1967. *Soil chemical analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, **38**: 226.

Jaga, P.K. and Singh, V. 2010. Effect of biofertilizer, nitrogen and sulphur on sorghum–mustard cropping system. *Proceedings of National Seminar on Soil Security for sustainable Agriculture* held at College of Agriculture, Nagpur.

Jain, S., Khaddar, V.K. Choudhary, S.K., Phadnis, S. and Nagar, R. 2004. Effect of organics and chemical fertilizer on the growth, yield attributes and yield of soybean-wheat cropping sequence, *Research on Crops*, **5**(1): 22-30.

Jat, A.L., Srivastava, V.K. and Singh, R.K. 2015. Effect of crop-establishment methods and integrated nitrogen management on productivity of hybrid rice (*Oryza sativa*)– wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **60**(3): 341-346.

Jat, S.L., Nepalia, V., Chaudhary, J. and Singh, D. 2014. Effect of nitrogen and weed management on productivity and quality of durum wheat (*Triticum durum*). *Indian Journal of Agronomy,* **59**(2): 281-285.

Katiyar, N.K., Rarawat, S., Pathak, R.K. and Kumar A. 2011. Effect of *Azotobacter* and nitrogen levels on yield and quality of wheat. *Annals of Plant and Soil Research*, **13**(2): 152-155.

Katkar, R.N., Sonune, B.A. and Kadu, P.R. 2011. Long–term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum–wheat system in Vertisols. *Annals of Plant and Soil Research*, **2**: 32-34.

Kaushik, M.K., Bishnoi, N.R. and Sumeriya, H.K. 2012. Productivity and economics of wheat as influenced by inorganic and organic sources of nutrients. *Annals of Plant and Soil Research*, **14**(1): 61-64.

Kavinder, Hooda, V.S. Malik, Y.P., Devraj, Harender and Kavita 2019. Effect of farm yard manure and nitrogen application on growth and productivity of wheat under long term experimental conditions. *Current Journal of Applied Science and Technology*, **35** (4): 1-7.

Khaddar, V.K. and Yadav, S. 2006. Effect of integrated nutrient management practices on soil microbial population in a soybean- wheat cropping sequence. *Journal of Environmental Research and Development,* **1**(2): 159-164.

Khambalkar, P.A., Tomar, P.S. and Verma, S.K. 2012. Long term effect of integrated nutrient management on productivity and soil fertility in pearl millet (*pennisetum glaucum*)- mustard (*brassica juncea*) cropping sequence. *Indian journal of agronomy* **57**(3):222-228.

Khan,S. and Khalil, S.K. 2014. Integrated use of organic and inorganic fertilizers in wheat and their residual effect on subsequent mung bean. *International Journal of Farming and Allied Sciences*. **3**(8): 835-844.

Khursheed, S., Arora, S. and Ali, T. 2012. Effect of different organic sources on biochemical properties in typical inceptisols of Jammu. *Progressive Agriculture* **12**(2): 348-353.

Kidane, T.A. 2014. Effect of integrated nutrient management on soil properties, wheat yield and residual effect on pearl millet. Ph.D thesis, Department of Agriculture Chemistry and Soil Science, CCSHAU, Hisar.

Kler, D.S. and Walia, S.S. 2006. Organic, integrated and chemical farming in wheat (*Triticum aestivum*) under maize (*Zea mays*) wheat cropping system. *Indian Journal of Agronomy*, **51**(1): 6-9.

Knapp, B.A., Ros, M. and Insam, H. 2010. Do composts affect the soil microbial community? In: Insam H, Franke–Whittle I, Goberna M (Eds), microbes at work: from wastes to resources. *Springer Berlin Heidelberg*, pp. 93-114.

Kotangale, V.S., Bharambe, P.R., Katore, J.R. and Ravankar, H.N. 2009. Effect of long term fertilizers on yield and uptake of nutrients under sorghum-wheat cropping sequence in vertisol. *Journal of Soil and Crops*, **19:** 320-323.

Kumar, A. 2008 Direct and residual effect of nutrient management in maize (*Zea mays*)- wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **53**(1): 37-41.

Kumar, A. 2013. Development of a liquid biofertilizer with indigenous microbial strains of Himachal Pradesh. Available on http://shodhganga.inflibnet.ac.in access on dated 27th October, 2014.

Kumar, A. and Dhar, S. 2010. Evaluation of organic and inorganic sources of nutrients in maize (*Zea mays* L.) and their residual effect on wheat (*Triticum aestivum* L.) under different fertility levels. *The Indian Journal of Agricultural Sciences,* **80**(5): 364-371.

Kumar, A. and Urmila 2018. Impact of biofertilizers in enhancing growth and productivity of wheat: A review. *International Journal of Chemical Studies* **6**(4): 360-362.

Kumar, A., Kumar, A.N., Dwivedi, A., Dhyani, B.P., Shahi, U.P. and Sengar, R.S. 2015. Production potential, nutrient uptake and factor productivity of scented rice in rice-wheat cropping system along with physico-chemical and microbiological properties under site specific integrated plant nutrient management. *Journal of Pure and Applied Microbiology*, **9**(2):1487-1497.

Kumar, A., Tripathi, H.P. and Yadav, D.S. 2007. Correcting nutrient for sustainable crop production. *Indian Journal of Fertilizer*, **2**: 37-44.

Kumar, P. and Pannu, R.K. 2012. Effect of different sources of nutrition and irrigation levels on yield, nutrient uptake and nutrient use efficiency of wheat. *International Journal of Life science and Pharma Research,* **1**(4): 187-192.

Kumar, S., Dahiya, R., Kumar, P., Jhorar, B.S. and Phogat, V.K. 2012. Long-term effect of organic materials and fertilizers on soil properties in pearl millet-wheat cropping system. *Indian Journal of Agricultural Research* **46**(2):161-166.

Kumawat, B.S. 2002. Effect of cropping systems and nitrogen levels on soil fertility. *Haryana Journal of Agronomy* **18**(2): 83-85.

Kurtz, W.G.W. and Larue, T.A.G. 1975. Effect of nitrogen source and carbon metabolism by *Azotobacter vinalandii* sp. grown in chemostat and batch culture. *Canadian Journal of Microbiology,* **21**: 738-741.

Kushare, B.M., Kushare, V.M. and Sandhan, V.S. 2009. Effect of N and P levels and biofertilizers on the growth and yield of wheat under late sown irrigated conditions. *International Journal of Agricultural Sciences*, **5**(2): 424-427.

Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Science Society of America Journal,* **42**: 421-428.

Laxminarayan, 2006. Effect of integrated use of inorganic and organic manure on soil properties yield and nutrient uptake in altisols of Mizoram. *Journal of the Indian Society of Soil Science* **54:**120-123.

Madhavi, Y., Goud, P.V., Reddy, K.M. and Saidulla, A. 2009. Effect of different levels of vemicompost, castor cake, poultry manure and biofertilizer on growth and yield of Indian spinach (*Beta vulgaris* var. Benghalensis Hort.). *Crop Research*, **37**(1, 2 &3): 148-151.

Mahmoud, M.R. 2006. Residual effect of compost and biofertilizer on maize yield, and some soil chemical properties. *Asian Journal of Agricultural Sciences,* **37**: 185-200.

Majumdar, B. Mandal, B. Bandopadhyay, P.K., Gangopadhyay, A. Mani, P.K., Kundu, A.L. and Majumdar, D. 2008. Organic amendment influence soil organic pools and crop productivity in a nineteen years old rice–wheat agro-ecosystem. *Soil Science society of America Journal,* **72**: 775-785.

Malghani, A.L., Malik, A.U., Sattar, A., Fiaz Hussain Abbas, G. and Hussain, J. 2012. Response of growth and yield of wheat to NPK fertilizer. *Science International,* **24**: 185-189.

Malik, B., Mandal, B., Bandopandhyay, P.K., Gangopadhyay, A., Mani, P.K., Kundu, A.L. and Majumdar, D. 2009. Organic amendment influence on soil organic pools and crop productivity in a nineteen years old rice-wheat agro-ecosystem. *Soil Science Society of American Journal*, **72**:775-785.

Manjhi, R.P., Mahapatra, P., Shabnam, S. and Yadava, M.S. 2016. Long term effect of nutrient management practices on performance of quality protein maize under maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping sequence. *Indian Journal of Agronomy* **61**(4): 436-442.

Mankotia, B.S. and Thakur, R.C. 2009 Integrated nutrient management in wheat (*Triticum aestivum*) and its residual effect on rice (*Oryza sativa*) in North-Western Himalayas. *Annals of Agricultural Research* **30**: 62-66.

Marozsan, M., Veres, S., Gajdos, E., Bakonyi, N., Toth, B. and Levai, L. 2009. The possible role of bio-fertilizers in agriculture. Zbornik Radova 44. Hrvatski i 4 Medunarodni Simpozij Agronoma, Opatija, Hrvatska, 16-20 585-588. [Book chapter. Conference paper].

Masto, R.E., Chhonkar, P.K., Singh, D. and Patra, A.K. 2006. Changes in soil biological and biochemical characteristics in a long-term field trial on a sub-tropical Inceptisol. *Soil Biology and Biochemistry,* **38**: 1577-1582.

Mathews, D.V., Patiland P.L. and Dasog, G.S. 2006. Effects of nutrients and bio fertilizers on yield and yield components of rice of coastal alluvium soil of Karnataka. *Karnataka Journal of Agricultural Sciences*, **19**(4): 799-803.

Maurya, R.N., Singh, U.P., Kumar, S., Yadav, A.C. and Yadav, R.A. 2019. Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.). *International Journal of Chemical Studies*, **7** (1): 770-773.

Meena, B.P., Kumar, A., Dotaniya, M.L., Jat, N.K. and Lal, B. 2014. Effect of organic sources of nutrients on tuber bulking rate, grades and specific gravity of potato tubers. *Proceedings of the National Academy of Sciences, India Section B: Biological Science*.

Meena, B.P., Kumar, A., Lal, B., Sinha, N.K., Tiwari, P.K., Dotaniya, M.L., Jat, N.K. and Meena, V.D. 2015. Soil microbial, chemical properties and crop productivity as affected by organic manure application in popcorn (*Zea mays* L. var. *everta*) *African Journal of Microbiology Research*, **9** (21), 1402-1408.

Meena, K.B., Alam, M.S., Singh, H., Bhat, M.A., Singh, A.K., Mishra, A.K. and Thomas, T. 2018. Influence of farmyard manure and fertilizers on soil properties and yield and nutrient uptake of wheat. *International Journal of Chemical Studies*, **6**(3): 386-390.

Meena, M.C., Dwivedi, B. S., Singh, D., Sharma, B.M., Kumar, K., Singh, R.V., Kumar, P. and Rana, D.S. 2012. Effect of integrated nutrient management on productivity and soil health in pigeonpea (*Cajanus cajan*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy,* **57**(4): 333-337.

Meena, R. and Meena, R.S. 2013. Effect of INM on yield, nutrient content and soil fertility status after harvest the wheat (*Triticum aestivum* L.) crop. *Environment and Ecology,* **31**(2B): 967-970.

Mehra, M. and Singh, S. 2007. Effect of INM on the growth, yield and nutrient uptake by wheat under Brahmi-Wheat cropping system. *Pantnagar Journal of Research,* **5**(2):105-107.

Mehta, S., Kumar, A., Thakur, N.P. and Bali, A.S. 2007. Effect of integrated nutrient management on wheat (*Triticum aestivum*) yield and soil properties. *Annals of Agricultural Research* **28(**1): 84-86.

Menaria, K. and Tenguria, R.K. 2008. Influence of sustainable agricultural practices on biological properties of vertisol soil with wheat crop in soybean-wheat cropping sequence. *Journal of Pure and Applied Microbiology*, **2**(2): 513-518.

Mitra, S., Roy, A., Saha, A.R., Maitra, D.N., Sinha, M.K., Mahapatra, B.S. and Saha, S. 2010. Effect of integrated nutrient management on fiber yield, nutrient uptake and soil fertility in jute (*Corchorus olitorius*). *Indian Journal of Agricultural Sciences,* **80**(9): 801-804.

Moharana, P.C., Sharma, B.M., Biswas, D.R., Dwivedi, B.S. and Singh, R.V. 2012. Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6-year-old pearl millet–wheat cropping system in an Inceptisol of subtropical India. *Field Crop Research* **136**: 32-41.

Mukherjee, D. 2014. Influence of integrated nutrient management on productivity, nutrient uptake and economics of maize (*Zea mays*)-yellow sarson (*Brassica rapa*) cropping system under rainfed mid hill condition. *Indian Journal of Agronomy* **59**(2): 221-228.

Olsen, S.R., Cole, C.V., Watanable, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate, USDA, Circular No. 939.

Pandey, I.B., Dwivedi, D.K. and Pandey, R.K. 2009. Integrated nutrient management for sustaining wheat (*Triticum aestivum*) production under late sown condition. *Indian Journal of Agronomy*, **54**: 306-309.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical Methods for Agricultural Workers.

Parewa, H.P., Yadav, J. and Rakshit, A. 2014. Effect of fertilizer levels, FYM and bioinoculants on soil properties in Inceptisol of Varanasi, Uttar Pradesh, India. *International Journal of Agriculture, Environment & Biotechnology.* **7**(3): 517-525.

Parmer, D.K., Sharma, P.K. and Sharma, T.R. 1998. Integrated nutrient supply system for 'DPP68' vegetable pea (*Pisum sativum* var. arvense) in dry temperature zone of H.P. *Indian Journal of Agricultural Sciences,* **68**: 84-86.

Pascual, J.A., Hernandez, T., Garcia, C. and Ayuso, M. 1998. Enzymatic activities in an arid soil amended with urban organic wastes: Laboratory experiment. *Postharvest Biology and Technology*, **64:** 131-138.

Patel, H.K., Sadhu, A.C., Lakum, Y.C. and Suthar, J.V. 2014. Response of integrated nutrient management on wheat (*Triticum Aestivum* L.) and its residual effect on succeeding crop. *International Journal of Agricultural Sciences and Veterinary Medicine*, **2**(4): 47-52.

Patidar, M. and Mali, A.L. 2002. Residual effect of farmyard manure, fertilizer and biofertilizer on succeeding wheat (*Triticum aestivum* L). *Indian Journal of Agronomy* **47**(1): 26-32.

Patil, A.S., Patel, H.K. and Chauhan, N.P. 2014. Yield, quality and monetary returns of summer pearlmillet (*Pennisetum glaucum* L.) as influenced by integrated nitrogen management and sowing methods. *Crop Research* **47**(1, 2 & 3): 24-28.

Paul, T., Bisht, P.S., Pandey, P.C., Singh, D.K. and Roy, S. 2013. Rice productivity and soil fertility as influenced by nutrient management in rice–wheat cropping system. *Indian Journal of Agronomy* **58**(4): 495-99.

Piper, C.S. 1950. *Soil and Plant Analysis*. Inter-Science Publication Inc., New York: 299.

Powon, M.P., Aguyoh, J.N. and Mwaja, V. 2005. Effects of inorganic fertilizers and farmyard manure on growth and tuber yield of potato. *African Crop Science Conference Proceedings,* **7**: 1089-1093.

Priyadarshani, A.K., Tomar, P.S. and Verma, S.K. 2012. Long-term effect of integrated nutrient management on productivity and soil fertility in pearlmillet (*Pennisetum glaucum*)–mustard (*Brassica juncea*) cropping sequence. *Indian Journal of Agronomy* **57**(3): 222-228.

Rajkhowa, D.J., Saikia, M. and Rajkhowa, K.M. 2003. Effect of vermicompost and levels of fertilizers on greengram. *Legumes research* **26**(1): 63-65.

Ram, T. and Mir, M.S. 2006. Effect of integrated nutrient management on yield and yield –attributing characters of wheat (*Triticum aestivum*). *Indian Journal of Agronomy,* **51**(3): 189-192.

Ramesh, P., Panwar, N.R., Singh, A.B. and Ramana, S. 2008. Effect of organic manures on productivity, soil fertility and economics of soyabean (*Glycine max*) – Durum Wheat (*Triticum durum*) cropping system under organic farming in vertisols. *Indian Journal of Agricultural Sciences,* **78**(12): 1033-1037.

Rasool, R., Kukal, S.S. and Hira, G.S. 2007. Soil physical fertility and crop performance as affected by long term application of FYM and inorganic fertilizers in rice–wheat system. *Soil & Tillage Research,* **96**(1): 64-72.

Rather, S.A. and Sharma, N.L. 2009. Effect of integrated nutrient management (INM) in wheat on soil properties and fertility status. *Asian Journal of Soil Science*, **4**(1): 55-57.

Rather, S.A. and Sharma, N.L. 2010. Effect of integrated nutrient management on productivity and nutrient uptake in wheat and soil fertility. *Asian Journal of Soil Science*; **4**(2): 208-210.

Richard, L.A. 1954. Diagnosis and improvement of saline and alkaline soils. USDA Hand Book No. 60.

Saiyad, M.M. 2014. Effect of liquid biofertilizers on yield attributes of brinjal (*Solanum melongena* L.). *Trends in Biosciences*, **7**(22):3754-3756.

Sandal, S.K., Sharma, P.K. and Bhushan, L. 2011. Effects of in-situ moisture conservation, seed soaking and fertilizer management on productivity of wheat in Himachal Pradesh. *Agropedology*, **21**(2): 25-34.

Scmidt, E.L. and Colwell, A.C. 1967. A Practical Manual of Soil Microbiology Laboratory Methods. Soil Bull, 7, FAO, Rome.

Sepehya, S., Subehia S.K., Rana S.S. and Negi S.C. 2012. Effect of integrated nutrient management on rice-wheat, yield and soil properties in a north western Himalayan region. *Indian Journal of Soil Conservation*, **40**(2): 135-140.

Sepat R.N., Rai R.K. and Dhar, S. 2010. Planting system and integrated nutrient management for enhanced wheat (*Triticum aestivum*) productivity. *Indian Journal of Agronomy* **55**(2): 114-118.

Shah, S., Gopinath, K.A., Mina, B.L., and Gupta, H.S. 2014. Influence of continuous application of inorganic nutrients to a Maize–Wheat rotation on soil enzyme activity and grain quality in a rainfed Indian soil. *European Journal of Soil Biology*, **44**: 521-531.

Shah, S.M., Bakht, S.A., Shah, J., Mohammad, S.M., Sharif, W. and Khan, M.M. A. 2012. Enhancing soil fertility and wheat productivity through integrated nitrogen management. *Communications in Soil Science and Plant Analysis,* **43**(11): 1499-1511.

Shah, Z. and Ahmad, M.I. 2006. Effect of integrated use of farm yard manure and urea on yield and nitrogen uptake of Wheat. *Journal of Agricultural and Biological Science,* **1** (1): 60-65.

Shaktawat, R.P.S. and Shekhawat, P.S. 2010. Soil fertility status as affected with and without farmyard manure in *Kharif* crops and fertilizer level in barley (*Hordeum vulgare*). *Indian Journal of agricultural Sciences* **80**(9): 791-794.

Sharma, A., Singh, H. and Nalwal, R.K. (2007) Effect of integrated nutrient management on productivity of wheat *(Triticum aestivum)* under limited and adequate irrigation supplies. *Indian Journal of Agronomy* **52**(2): 120-123.

Sharma, A., Singh, H., Pannu, R.K., Nanwal, R K. and Singh, K.P. 2006. Effect of integrated nutrient management on yield and nutrient uptake in wheat (*Triticum aestivum* (L.) Emend. Fiori & Paol.) under adequate and limited irrigation. *Haryana Journal of Agronomy,* **22**(1): 1-4.

Sharma, G.D, Thakur, R.., Somraj, Kauraw, D.L. and Kulhare, P.S. 2013. Impact of integrated nutrient management on yield, nutrient uptake, protein content of wheat (*Triticum aestivum*) and soil fertility in a typic haplustert. *The Bioscan,* **8**(4): 1159-1164.

Sharma, K.C. 2009. Integrated nitrogen management in fodder oat (*Avena sativa*) in hot arid ecosystem of Rajasthan. *Indian journal of Agronomy.* **54**(4): 459-464.

Sharma, P.K. and Manohar, S.S. 2002. Response of wheat (*Triticum aestivum*) to nitrogen and sulphur and their residual effect on succeeding pearl millet (*Pennisetum glaucum*). *Indian Journal of Agronomy* **47**(4): 473-476.

Sharma, R. 2013. Effect of long term integrated nutrient management system on soil and crop productivity in Rice -Wheat crop sequence. Indian ETD Repository @ inflibnet, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Department of Agronomy Forages and Grassland Management.

Sharma, R., Dahiya, S., Rathee, A., Singh, D., Nandal, J.K. and Malik, R.K. 2009. Effect of INM on growth, yield, economics and soil fertility in rice-wheat cropping system. *Indian Journal of Fertilizers*, **5**(3): 31-34.

Sharma, S.K. 2011. Environmental chemistry, published by Rastogi, SK, for Krishna prakashan media (P) Ltd, Meerut, UP, 128.

Shinde, D.B. and Bangar, N.D. 2003. Studies on dual inoculation of nitrogenous and phosphatic bacterial cultures in sugarcane. *Journal of Maharashtra Agricultural University,* **28**: 190-192.

Shukla, L., Tyagi, S.P., Manjunath R, Jeetender, J. and Saxena, A.K. 2013. Effect of vermicompost and microbial inoculants on soil health, growth and yield of HD 2687 wheat (*Triticum aestivum*). *Indian Journal of Agricultural Sciences,* **83**(3): 34-38.

Singh, A.B., Ramesh, P., Panwar, N.R., Ramana, S. 2008a. Nutritional quality of soybean (*Glycine max*), wheat (*Triticum durum*) and chickpea (*Cicer arietinum*) and soil biological properties as influenced by different organic manures. *The Indian Journal of Agricultural Sciences*, **78**(9): 781-784.

Singh, A.B., Ramesh, P., Panwar, N.R., Ramana, S. 2008. Nutritional quality of soybean (*Glycine max*), wheat (*Triticum durum*) and chickpea (*Cicer arietinum*) and soil biological properties as influenced by different organic manures. *The Indian Journal of Agricultural Sciences*, **78**(9): 781-784.

Singh, D.P. and Singh, D. 2017. Effect of nitrogen and FYM on yield, quality and uptake of nutrients in wheat (*Triticum aestivum*). *Annals of Plant and Soil Research*, **19** (2): 232-236.

Singh, G., Kumar, S., Sidhu, G.S. and Kaur, R. 2018. Effect of integrated nutrient management on yield of wheat (*Triticum aestivum* L.) under irrigated conditions. *International Journal of Chemical Studies*, **6** (2): 904-907.

Singh, G., Sharma, G.L., Golada, S.L. and Choudhary, R. 2012a. Effect of integrated nutrient management on quality protein maize (*Zea mays* L.). *Crop Research,* **44**: 26-29.

Singh, G., Singh, S. and Singh, S.S. 2013(b). Integrated nutrient management in rice and wheat crop in rice- wheat cropping system in lowlands. *Annals of Plant and Soil Research,* **15**(1): 1-4.

Singh, H. and Bhadoria, H.S. 2013. Response of wheat to *Azotobacter*, nitrogen and sulphur application in an alluvial soil. *Annals of agricultural research* **34**(4): 337-341.

Singh, J. and Singh, C.M. 2001. Effect of potassium application in rice –wheat cropping system. *Indian Journal of Agronomy,* **45**(1): 12-20.

Singh, K.L., Nandal, K.P, Hari Om, D.P. and Thakral, S.K. 2012b. Effect of organic and inorganic sources of fertilizer on growth parameters and productivity of wheat in rice-wheat system. *Annals of Biology*, **28**(1): 36-40.

Singh, N.K., Chaudhary, F.K. and Patel, D.B. 2012c. Effectiveness of *Azotobacter* bio- inoculent for wheat grown under dryland condition. *Journal of Environmental Biology*. **34**: 927-932.

Singh, R. and Rai, R.K. 2004. Yield attributes, yield and quality of soybean (*Glycine max*) as influenced by integrated nutrient management. *Indian Journal of Agronomy* **49**(4): 271-274.

Singh, R. and Singh, K.P. 2005. Nutrient uptake and quality of wheat as affected by organic manures and inorganic fertilizers. *Haryana Journal of Agronomy*; **21**(2): 207-208.

Singh, R., Babu, S., Avasthe, R.K., Yadav, G.S., Chettri, T.K., Phempunadi, C.D. and Chatterjee, T. 2015. Bacterial inoculation effect on soil biological properties, growth, grain yield, total phenolic and flavonoids contents of common buckwheat (*Fagopyrum esculentum* Moench) under hilly ecosystems of North-East India. *African Journal of Microbiology Research,* **9**(15), 1110-1117.

Singh, R., Singh, B. and Patidar, M. 2008d. Effect of preceding crops and nutrient management on productivity of wheat (*Triticum aestivum*)-based cropping system in arid region. *Indian Journal of Agronomy,* **53**: 267-272.

Singh, R.K., Agrawal, R.L. and Singh, S.K. 2007. Integrated nutrient management in wheat (*Triticum aestivum*). *Annals of Agricultural Research,* **28**(1): 20-24.

Singh, R.V. and Kumar, R. 2010. Effect of organic and inorganic fertilizers on growth yield and quality and nutrients uptake of wheat under late sown condition. *Progressive Agriculture*, **10**(2): 341-344.

Singh, S.P., Vivek and Kumar, R. 2013(a). Effect of integrated nutrient management practices on soil health and economics of wheat (*Triticum aestivum* L.). *Advances in Plant Sciences*, **26**(1):125-128.

Singh, Y.V., Singh, K.K. and Dhar, S. 2011b. Productivity of wheat and soil organic carbon status under integrated use of organic and inorganic fertilizers. *Annals of Agricultural Research,* **32**: 6-10.

Snell, F.D. and Snell, C.T. 1959. Colorimetric methods of analysis *3rd Ed. Vol. IID. Van Nostrand Inc.* New York.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science,* (**25): **259-260.

Suke, S.N., Deotale, R.D., Hiradeve, P., Deogirkar, M. and Sorte, N.V. 2011. Effect of nutrient and biofertilizers of chemical and biochemical parameters of maize (*Zea mays* L.). *Journal of Soil and Crops,* **21**: 107-112.

Sushila, R. 1998. Integrated nitrogen management in wheat under limited water supply. *Ph.D. Thesis*, *Indian Agricultural Research Institute*, New Delhi.

Swaroop, A. and Yaduvanshi, R.H. (2000) Three Decades of All India Coordinated Research Project on long-term fertilizer experiments to study change in soil quality, crop productivity and sustainability. *Indian Institute of Soil Science* Bhopal, India pp. 59.

Tetarwal, J.P., Ram, B. and Meena, D.S. 2011. Effect of integrated nutrient management on productivity, profitability, nutrient uptake and soil fertility in rainfed maize (*Zea mays)*. *Indian Journal of Agronomy* **56**(4): 373-376.

Thakur, R., Sawarkar, S.D., Vaishya, U.K. and Singh, M. 2011. Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. *Journal of the Indian Society of Soil Science*, **59**(1): 74-81.

Tiwari, A. Dwivedi, A.K. and Dixit, P.R. 2002. Long term influence of organic and inorganic fertilization on soil fertility and productivity of soybean-wheat system in a Vertisol. *Journal of Indian Society of Soil Science* **50**: 472-475.

Totawat, K.L., Somani, L.L., Singh, R. and Singh, G. 2000. Integrated nitrogen management in maize-wheat cropping sequence on haplustalfs of sub-humid southern plains of Rajasthan. In: Proceeding of International Conference on Managing Natural Resources for Sustainable Agricultural Production in the 21st Century, New Delhi, **3**: 923-924.

United States Department of Agriculture 2018. World Agricultural Production, Circular series, WAP, 8-18.

Upadhyay, V.B., Jain, V., Vishwakarma, S.K. and Kumar, A.K. 2011. Production potential, soil health water productivity and economic of rice (*Oryza sativa*) based cropping system under different nutrients sources. *Indian Journal of Agronomy,* **56**(4): 311-316.

Urkarkar, J.S., Tiwari, A., Chitale, S. and Bajpai, R.K. 2010. Influence of long- term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Inceptisols. *Indian Journal of Agricultural Sciences* **80**(3): 208-212.

Veihmeyer F.J and Hendrickson A.H. 1931. The moisture equivalent as a measure of field capacity of soils. *Soil Science*, **32**: 181-194.

Verma, G. and Mathur, A.K. 2009. Effect of integrated nutrient management on active pools of soil organic matter under maize-wheat system of a typic haplustept. *Journal of the Indian Society of Soil Science,* **57** (3): 317-322.

Verma, G., Mathur, A.K., Bhandari, S.C. and Kanthaliya, P.C. 2010. Long-term effect of integrated nutrient management on properties of a Typic Haplustept under maize-wheat cropping system. *Journal of the Indian Society of Soil Science* **58**(1): 299–302.

Verma, V.K., Chaudhry, S., Singh, V., Gupta, S.K. and Kumar, H. 2014. Effect of integrated soil fertility management practices on production and productivity of wheat (*Triticum aestivum*) in alluvial soils of central plain zone of Uttar Pradesh. *International Journal of Agricultural Sciences,* **10**(2): 735-738.

Vidyavathi, G., Dasog, S., Babalad, H.B., Hebsur, N.S., Gali, S.K., Patil, S.G. and Alagawadi, A.R. 2011. Influence of nutrient management practices on crop response and economics in different cropping systems in a Vertisol. Karnataka *Indian Journal of Agricultural Sciences,* **24**(4):455-460.

Walkley, A. and Black, C.A. 1934. An examination of different methods for determining soil organic matter and a proposed modifications of the chromic acid titration method. *Soil Science,* **37**: 29-38.

Wu, S.C., Cao, Z.H., Li, Z.G., Cheung, K.C. and Wong, M.H., 2005. Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: a greenhouse trial. *Geoderma,* **125**, 155-166.

Yadav, D.S. and Kumar, A. 2002. Long term effects of organic manures on productivity and soil fertility in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) pp 65-67 in Extended Summaries. Vol. 1, 2nd International Agronomy Congress, New Delhi, November 26-30, 2002, *Indian Society of Agronomy*, IARI, New Delhi

Yadav, R.S., Yadav, P.C. and Dahama, A.K. 2003. Integrated nutrient management in wheat (*Triticum aestivum*)-mungbean (*Phaseolus radiates*) cropping sequence in arid region. *Indian Journal of Agronomy* **48**(1): 23-26.

Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts

Subhita Kumari* **Dr. Mahendra Sharma****
Research Scholar Major Advisor

ABSTRACT

A field experiment entitled **"Effect of Fertility Levels, Organic Sources and Bio-inoculants on Soil Properties, Nutrient Uptake and Production of Wheat (*Triticum aestivum* L.) in Haplustepts"** was conducted at Agronomy Farm, Rajasthan College of Agriculture, Udaipur during *rabi* season in 2015-16 and 2016-17. The experiment consisted of 24 treatment combinations comprising of three levels of fertility (50, 75 and 100 per cent RDF), four organic sources (FYM @ 5 and 10 t ha^{-1}, vermicompost @ 2.5 and 5 t ha^{-1}), and two bio- inoculations (Without inoculation and *Azotobacter* + PSB). Experiment was conducted under factorial randomized block design replicated thrice taking wheat var. Raj- 4037 as test crop.

The results of the study showed that enrichment of soil with 75 per cent RDF significantly increased the effective tillers m^{-1} row length, number of grains $spike^{-1}$, test weight, grain, straw and biological yield, nutrient content *viz*. N, P, K, Fe, Mn, Zn and Cu and protein content in grain over 50 per cent RDF. However, nutrient uptake by grain and straw as well as total uptake by crop increased significantly up to 100 per cent RDF. Further results showed that 100 per cent RDF decreased the bulk density and particle density and increased the water holding capacity of soil, while organic carbon, available N, P, K, Fe, Mn, Zn and Cu content of soil increased significantly with 75 per cent RDF as compare to 50 per cent RDF. Dehydrogenase activity and microbial (bacterial and fungal) population of soil significantly enhanced with the application of 75 per cent RDF over 50 per cent RDF. The maximum monetary return of ₹ 63688 with benefit cost ratio of 2.28 were obtained with 75% RDF.

Application of vermicompost @ 5 t ha^{-1} significantly increased the yield attributes and yields *viz.* effective tillers m^{-1} row length, number of grains $spike^{-1}$, test weight, grain, straw and biological yield, nutrient content and uptake as well as total uptake of N, P, K, Fe, Mn, Zn and Cu and protein content in grain other than organic

* Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, RCA, Udaipur – 313 001
** Professor, Department of Soil Science and Agricultural Chemistry, RCA, Udaipur – 313 001

manures. Further results showed that vermicompost @ 5 t ha^{-1} decreased the bulk density and particle density and increased the water holding capacity, available N, P, K, Fe, Mn, Zn and Cu content of soil, however, organic carbon increased significantly with 10 t FYM ha^{-1}. Dehydrogenase activity and microbial (bacterial and fungal) population of soil significantly enhanced with 5 t vermicompost ha^{-1}. The maximum monetary return of ₹ 64661 were found with vermicompost @ 5 t ha^{-1} over other treatments however highest benefit cost ratio of 2.38 were observed in vermicompost @ 2.5 t ha^{-1} over control.

Combined use of vermicompost @ 5 t ha^{-1} along with 75% RDF significantly increased the grain, straw and biological yields of crop, nitrogen, phosphorus and potassium uptake by grain, straw and total uptake over other treatments but remained at par with FYM @ 10 t ha^{-1} + 100 per cent RDF and vermicompost @ 5 t ha^{-1} + 100 per cent RDF.

Dual inoculations of *Azotobacter* + PSB significantly increased the effective tillers m^{-1} row length, number of grains $spike^{-1}$, test weight, grain, straw and biological yield, content and uptake of N, P, K, Fe, Mn, Zn and Cu by crop, water holding capacity, available N, P and K content of soil than without inoculation. Dehydrogenase activity and microbial (bacterial and fungal) population of soil significantly enhanced with dual inoculation of seed with *Azotobacter* + PSB. The maximum monetary return of ₹ 63711 with benefit cost ratio of 2.28 were obtained with dual inoculation of *Azotobacter* + PSB.

हेप्लुस्टेप्स में गेहूँ (*ट्रिटिकम एस्टीवम* एल.) में उर्वरता स्तरों, जैविक खाद व जीवाणु खाद का मृदा गुणों, पोषक तत्व अवशोषण तथा उत्पादकता पर प्रभाव

सुभिता कुमारी[*]
शोधकर्ता

डॉ. महेन्द्र शर्मा[**]
मुख्य सलाहकार

अनुक्षेपण

राजस्थान कृषि महाविद्यालय के शस्य विज्ञान प्रक्षेत्र में प्रक्षेत्र परिक्षण **"हेप्लुस्टेप्स में गेहूँ (*ट्रिटिकम एस्टीवम* एल.) में उर्वरता स्तरों, जैविक खाद व जीवाणु खाद का मृदा गुणों, पोषक तत्व अवशोषण तथा उत्पादकता पर प्रभाव"** शीर्षकान्तर्गत रबी वर्ष 2015–16 एवं 2016–17 में क्षेत्रीय परीक्षण लगाया गया। परीक्षण में कुल 24 उपचार संयोजन सम्मिलित किये गये, जिसमें उर्वरकता के 3 स्तर (50, 75 एवं 100 प्रतिशत उर्वरकों की सिफारिश खुराक), जैविक खादों के 4 स्तर (गोबर की खाद 5 टन व 10 टन प्रति हैक्टेयर तथा केंचुए की खाद 2.5 टन व 5 टन प्रति हैक्टेयर) एवं जीवाणु खाद के 2 स्तर (बिना जैव उर्वरक एवं एजोटोबेक्टर+फॉस्फेट विलायक जीवाणु) लिये गये। गेहूँ की राज–4037 किस्म को परीक्षण फसल के रूप में लेते हुये सभी उपचारों को यादृच्छिक खण्ड अभिकल्पना विधि के अन्तर्गत 3 पुनरावृतियों के साथ प्रतिपादित किया गया।

अध्ययन के परिणामों ने यह दर्शाया कि 75 प्रतिशत उर्वरकों की सिफारिश खुराक का मृदा में संवर्द्धन करने से 50 प्रतिशत उर्वरकों की सिफारिश खुराक की तुलना में प्रभावी कल्लों की संख्या, प्रति मीटर पंक्ति लम्बाई, बाली में दानों की संख्या, परीक्षण भार, दाना, भूसा व जैविक उपज, नत्रजन, फॉस्फोरस, पोटाश, लोहा, मैगनीज, जस्ता व कॉपर की मात्रा दानों में प्रोटीन की मात्रा में सार्थक वृद्धि प्राप्त हुई है। जबकि इन पोषक तत्वों के दाना, भूसा व कुल अवशोषण में 100 प्रतिशत उर्वरकों की सिफारिश खुराक से मृदा की स्थूल घनत्व व कण घनत्व में कमी तथा जल धारण क्षमता में सार्थक वृद्धि पायी गयी जबकि 75 प्रतिशत उर्वरकों की सिफारिश खुराक का मृदा में संवर्द्धन करने से 50 प्रतिशत उर्वरकों की सिफारिश खुराक की तुलना में जैविक कार्बन, उपलब्ध नत्रजन, फॉस्फोरस, पोटाश, लोहा, मैगनीज, जस्ता व कॉपर की मात्रा में सार्थक वृद्धि हुई। 75 प्रतिशत उर्वरकों की सिफारिश खुराक से 50 प्रतिशत सिफारिश खुराक की तुलना में डिहाइड्रोजिनेज क्रिया एवं सूक्ष्म जीवाणुओं (जीवाणु एवं फंजाई) की संख्या में सार्थक वृद्धि हुई। अधिकतम वित्तीय लाभ ₹ 63688 व लाभ लागत अनुपात (2.28) 75 प्रतिशत उर्वरकों की सिफारिश खुराक से प्राप्त हुआ।

* विद्यावाचस्पति शोध छात्रा, मृदा विज्ञान एवं कृषि रसायन विभाग, राजस्थान कृषि महाविद्यालय, उदयपुर
** आचार्य, मृदा विज्ञान एवं कृषि रसायन विभाग, राजस्थान कृषि महाविद्यालय, उदयपुर

केंचुए की खाद के 5 टन प्रति हैक्टेयर प्रयोग से उपज एवं उपज विशेषताओं जैसे प्रभावी कल्लों की संख्या, प्रति मीटर पंक्ति लम्बाई, बाली में दानो की संख्या, परीक्षण भार, दाना, भूसा व जैविक उपज, नत्रजन, फॉस्फोरस, पोटाश, लोहा, मैगनीज, जस्ता व कॉपर की मात्रा व पादप द्वारा इनका अवशोषण व दानों में प्रोटीन की मात्रा में सार्थक वृद्धि हुई।

मृदा को 5 टन केंचुए की खाद से सवंर्द्धित करने से मृदा के स्थूल घनत्व व कण घनत्व में कमी, जलधारण क्षमता, उपलब्ध नत्रजन, फॉस्फोरस, पोटाश, लोहा, मैगनीज, जस्ता व कॉपर की मात्रा में सार्थक वृद्धि हुई जबकी 10 टन गोबर की खाद से जैविक कार्बन से सार्थक वृद्धि पायी गयी। 5 टन केंचुए की खाद प्रति हैक्टेयर के प्रयोग से डिहाइड्रोजिनेज क्रिया एवं सूक्ष्म जीवाणुओं (जीवाणु एवं फंजाई) की संख्या में सार्थक वृद्धि हुई। अधिकतम वित्तीय लाभ ₹ 64661, 5 टन प्रति हैक्टेयर केंचुए की खाद से व अधिकतम लागत (2.38) 10 टन प्रति हैक्टेयर गोबर की खाद के प्रयोग से प्राप्त हुआ।

दूसरें स्तरों की तुलना में वर्मी कम्पोस्ट 5 टन प्रति हैक्टेयर के साथ 75 प्रतिशत उर्वरकों की सिफारिश खुराक के सयुंक्त प्रयोग से दानों की उपज, भूसे की उपज और जैविक उपज, दानें, भूसे और कुल अवशोषण में नाईट्रोजन, फॉस्फोरस और पोटेशियम के अवशोषण में सार्थक वृद्धि हुई जबकि 10 टन गोबर की खाद + 100 प्रतिशत उर्वरकों की सिफारिश खुराक और 5 टन वर्मी कम्पोस्ट + 100 प्रतिशत उर्वरकों की सिफारिश खुराक के साथ समानता पायी गयी।

बीजों का द्विसंचयन एजोटोबैक्टर+फॉस्फेट विलायक जीवाणुओं से करनें पर प्रभावी कल्लों की संख्या, परीक्षण भार, दाना, भूसा व जैविक उपज, नत्रजन, फॉस्फोरस, पोटाश, लोहा, मैगनीज, जस्ता व कॉपर की मात्रा व इनका पादप द्वारा अवशोषण, मृदा जल धारण क्षमता व मृदा की उपलब्ध नत्रजन, फॉस्फोरस व पोटाश की मात्रा में जैव उर्वरक की तुलना में सार्थक वृद्धि पायी गयी। एजोटोबैक्टर+फॉस्फेट विलायक जीवाणुओं के प्रयोग से डिहाइड्रोजिनेज क्रिया एवं सूक्ष्म जीवाणुओं (जीवाणु एवं फंजाई) की संख्या में सार्थक वृद्धि हुई। अधिकतम वित्तीय लाभ ₹ 63711 व लाभ अनुपात 2.28 एजोटोबैक्टर+फॉस्फेट विलायक जीवाणुओं के प्रयोग से प्राप्त हुआ।

APPENDIX - I

Analysis of variance (MSS) for yield attributes of wheat

Source of variation	**d.f.**	**M.S.S.**					
		Effective tillers m^{-1} row length		**No. of grains $spike^{-1}$**		**Test weight (g)**	
		2015-16	**2016-17**	**2015-16**	**2016-17**	**2015-16**	**2016-17**
Replication (R)	2	50.093	60.88	6.63	10.77	12.119	10.029
Fertility levels (F)	2	1712.01*	2047.07*	289.48*	271.62*	73.574*	61.524*
Organic sources (O)	3	1848.69*	1583.82*	306.85*	280.281*	85.241*	73.097*
Bio-inoculants (B)	1	600.93*	876.98*	105.61*	103.951*	62.725*	113.785*
F x O	6	438.94	441.05	74.25	62.95	102.39	107.711
F x B	2	615.66	605.05	100.37	79.60	71.354	38.031
O x B	3	522.51	240.40	82.64	40.87	102.42	60.082
F x O x B	6	400.06	245.90	64.02	38.70	73.66	71.170
Error	46	61.71	88.41	9.63	15.027	5.824	19.166

*Significant at 5% level of significance

APPENDIX - II

Pooled analysis of variance (MSS) for yield attributes of wheat

Source of variation	d.f.	M.S.S.		
		Effective tillers m^{-1} row length	No. of grains $spike^{-1}$	Test weight (g)
Year (Y)	1	187.2475	48.6302	60.9472
Replication (R)	4	55.4885	8.7071	11.0744
Fertility levels (F)	2	3751.5517*	560.8256*	130.6382*
Organic sources (O)	3	3402.6178*	584.1433*	153.8725*
Bio-inoculants (B)	1	1464.9084*	209.5637*	172.7380*
F x Y	2	7.5391	0.2854	4.4605
O x Y	3	29.9005	2.9900	4.4669
F x O	6	234.0848	46.2996	125.5587
F x O x Y	6	645.9150	90.9141	84.5495
F x B	2	202.0057	23.8381	35.0427
O x B	3	715.9277	113.6942	109.4674
F x O x B	6	363.2943	67.4189	84.5550
B x Y	1	13.0049	0.0033	3.7733
F x B x Y	2	1018.7117	156.1487	74.3427
O x B x Y	3	46.9927	9.8257	53.0449
F x O x B x Y	6	282.6747	35.3097	60.2854
Error	92	75.0655	12.3336	12.4957

APPENDIX - III

Analysis of variance (MSS) for yield and harvest index of wheat

Source of variation	d.f.	M.S.S.							
		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})		Biological yield (q ha^{-1})		Harvest index (%)	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	5.2327	6.7646	62.1704	5.20652	31.3668	17.0040	9.896	0.933
Fertility levels (F)	2	361.92*	428.980*	1170.99*	1497.955*	2833.86*	3524.04*	4.0342	4.340
Organic sources (O)	3	387.88*	335.904*	503.668*	777.541*	1775.11*	2107.29*	15.98	11.23
Bio-inoculants (B)	1	148.72*	207.728*	214.86*	275.979*	721.11*	962.57*	9.04	5.074
F x O	6	82.6563	69.5118	426.515	735.827	317.76	457.197	83.30	114.98
F x B	2	144.095	84.1678	169.721	353.393	35.496	167.719	78.13	68.24
O x B	3	77.9322	37.0222	538.582	209.738	670.64	314.645	56.34	13.92
F x O x B	6	74.1949	46.3521	297.733	1067.644	316.39	1014.22	53.89	107.79
Error	46	12.4711	18.41133	30.6490	43.541	50.581	67.947	4.21	7.004

*Significant at 5% level of significance

APPENDIX - IV

Pooled analysis of variance (MSS) for yield and harvest index of wheat

Source of variation	d.f.	M.S.S.			
		Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Year (Y)	1	35.3965	101.2001	256.298	3.1338
Replication (R)	4	5.9987	33.6885	24.185	5.4149
Fertility levels (F)	2	789.4778*	2657.5998*	6337.848*	6.8228
Organic sources (O)	3	718.1381*	1258.3274*	3862.996*	25.5769
Bio-inoculants (B)	1	353.9980*	488.9299*	1674.986*	13.8330
F x Y	2	1.4252	11.3527	20.059	1.5518
O x Y	3	5.6523	22.8822	19.411	1.6422
F x O	6	30.0670	108.8662	171.248	15.0904
F x O x Y	6	122.1011	1053.4763	603.714	183.1946
F x B	2	35.6905	33.0606	133.101	1.8391
O x B	3	106.0711	703.4996	950.734	60.3670
F x O x B	6	67.1114	816.1583	941.872	76.3957
B x Y	1	2.4584	1.9101	8.702	0.2845
F x B x Y	2	192.5731	490.0549	70.115	144.5397
O x B x Y	3	8.8833	44.8211	34.556	9.9043
F x O x B x Y	6	53.4357	549.2198	388.750	85.2980
Error	92	15.4412	37.0951	59.264	5.6117

APPENDIX - V

Analysis of variance (MSS) for nitrogen and protein content in wheat

Source of variation	d.f.	M.S.S.					
		Nitrogen content (%)				Protein content in grain (%)	
		Grain		Straw			
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	0.0088	0.01718	0.0008	0.00244	0.3420	0.67095
Fertility levels (F)	2	0.2239*	0.28879*	0.0282*	0.03127*	8.7462*	11.28085*
Organic sources (O)	3	0.0764*	0.06639*	0.0070*	0.00573*	2.9837*	2.59331*
Bio-inoculants (B)	1	0.2258*	0.10673*	0.0285*	0.01078*	8.8187*	4.16907*
F x O	6	0.0534	0.21366	0.0057	0.02277	2.0872	8.34601
F x B	2	0.1294	0.14227	0.0159	0.01695	5.0535	5.55750
O x B	3	0.0432	0.15613	0.0073	0.02434	1.6878	6.09872
F x O x B	6	0.0495	0.17081	0.0068	0.01977	1.9333	6.67242
Error	46	0.0129	0.01540	0.0024	0.00167	0.5044	0.60169

*Significant at 5% level of significance

APPENDIX - VI

Pooled analysis of variance (MSS) for nitrogen and protein content in wheat

Source of variation	d.f.	M.S.S.		
		Nitrogen content (%)		Protein content in grain (%)
		Grain	Straw	
Year (Y)	1	0.02388117	0.0047781	0.9328583
Replication (R)	4	0.01296570	0.0016127	0.5064727
Fertility levels (F)	2	0.50971410*	0.0593603*	19.9107071*
Organic sources (O)	3	0.14142988*	0.0125503*	5.5246048*
Bio-inoculants (B)	1	0.32146773*	0.0371802*	12.5573330*
F x Y	2	0.00297868	0.0000737	0.1163547
O x Y	3	0.00134110	0.0001544	0.0523867
F x O	6	0.03038908	0.0032846	1.1870735
F x O x Y	6	0.23670180	0.0252039	9.2461640
F x B	2	0.14272789	0.0148782	5.5753081
O x B	3	0.13141605	0.0179954	5.1334393
F x O x B	6	0.11626936	0.0129752	4.5417719
B x Y	1	0.01101827	0.0021156	0.4304014
F x B x Y	2	0.12891345	0.0179470	5.0356817
O x B x Y	3	0.06791904	0.0136669	2.6530876
F x O x B x Y	6	0.10403815	0.0136175	4.0639903
Error	92	0.01415785	0.0020447	0.5530409

APPENDIX - VII

Analysis of variance (MSS) for phosphorus and potassium content in wheat

Source of variation	d.f.	M.S.S.							
		Phosphorus content (%)				Potassium content (%)			
		Grain		Straw		Grain		Straw	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	0.0003	0.00090	0.0001	0.00023	0.0002	0.00014	0.0013	0.00085
Fertility levels (F)	2	0.0091*	0.01056*	0.0023*	0.00264*	0.0111*	0.01242*	0.0873*	0.0941*
Organic sources (O)	3	0.0036*	0.00428*	0.0009*	0.00107*	0.0093*	0.01070*	0.0730*	0.08007*
Bio-inoculants (B)	1	0.0089*	0.00916*	0.0022*	0.00229*	0.0177*	0.01432*	0.1389*	0.10588*
F x O	6	0.0019	0.00720	0.0005	0.00180	0.0076	0.00758	0.0598	0.06060
F x B	2	0.0075	0.00669	0.0019	0.00167	0.0086	0.00828	0.0672	0.06972
O x B	3	0.0019	0.00833	0.0005	0.00208	0.0045	0.00387	0.0349	0.03224
F x O x B	6	0.0026	0.00667	0.0006	0.00167	0.0068	0.00663	0.0533	0.04851
Error	46	0.0008	0.00061	0.0002	0.00015	0.0008	0.00087	0.0065	0.00682

*Significant at 5% level of significance

APPENDIX - VIII

Pooled analysis of variance (MSS) for phosphorus and potassium content in wheat

Source of variation	d.f.	M.S.S.			
		Phosphorus content (%)		Potassium content (%)	
		Grain	Straw	Grain	Straw
Year (Y)	1	0.0048655	0.0012164	0.002848	0.020316
Replication (R)	4	0.0005841	0.0001460	0.000150	0.001071
Fertility levels (F)	2	0.0196296*	0.0049074*	0.023536*	0.181351*
Organic sources (O)	3	0.0076814*	0.0019203*	0.019986*	0.152873*
Bio-inoculants (B)	1	0.0180362*	0.0045091*	0.031950*	0.243645*
F x Y	2	0.0000351	0.0000088	0.000018	0.000080
O x Y	3	0.0002009	0.0000502	0.000032	0.000245
F x O	6	0.0012802	0.0003200	0.015157	0.119780
F x O x Y	6	0.0078298	0.0019575	0.000058	0.000666
F x B	2	0.0042001	0.0010500	0.016846	0.136876
O x B	3	0.0061192	0.0015298	0.008309	0.066978
F x O x B	6	0.0042257	0.0010564	0.013368	0.101175
B x Y	1	0.0000011	0.0000003	0.000090	0.001118
F x B x Y	2	0.0099699	0.0024925	0.000003	0.000042
O x B x Y	3	0.0040635	0.0010159	0.000014	0.000158
F x O x B x Y	6	0.0050126	0.0012531	0.000057	0.000613
Error	92	0.0006959	0.0001740	0.000844	0.006635

APPENDIX - IX

Analysis of variance (MSS) for iron and manganese content in wheat

Source of variation	d.f.	M.S.S.							
		Iron content (mg kg^{-1})				Manganese content (mg kg^{-1})			
		Grain		Straw		Grain		Straw	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	8.8891	8.14067	106.5301	2.46233	0.8782	1.22473	4.9929	1.18716
Fertility levels (F)	2	194.6722*	173.6784*	339.765*	384.8354*	18.842*	25.4316*	38.4161*	44.6278*
Organic sources (O)	3	255.4029*	235.2948*	740.208*	547.2321*	8.8363*	6.6492*	9.5983*	13.8980*
Bio-inoculants (B)	1	187.6042*	155.6030*	501.150*	585.6978*	30.146*	7.3756*	6.4241*	12.3154*
F x O	6	251.3815	271.96677	588.2516	649.05398	5.9524	15.64483	31.7892	38.08903
F x B	2	261.9610	315.16918	377.5281	664.22629	14.7526	8.88253	13.3518	16.71800
O x B	3	244.6552	275.45404	649.8092	585.91526	8.3615	16.53361	29.4995	31.84110
F x O x B	6	118.7418	107.84822	272.7887	236.06318	1.6935	12.56537	26.0876	26.27427
Error	46	22.5686	23.22767	30.4418	36.17850	1.5242	1.14036	1.3279	2.60613

*Significant at 5% level of significance

APPENDIX - X

Pooled analysis of variance (MSS) for iron and manganese content in wheat

Source of variation	**d.f.**	**M.S.S.**			
		Iron content (mg kg^{-1})		**Manganese content (mg kg^{-1})**	
		Grain	**Straw**	**Grain**	**Straw**
Year (Y)	1	105.71329	155.0203	6.537317	31.31422
Replication (R)	4	8.51489	54.4962	1.051462	3.09001
Fertility levels (F)	2	367.49658*	721.6342*	43.991285*	82.87574*
Organic sources (O)	3	490.37521*	1278.7289*	15.097786*	23.17271*
Bio-inoculants (B)	1	342.45968*	1085.2017*	33.672302*	18.26452*
F x Y	2	0.85412	2.9670	0.282597	0.16816
O x Y	3	0.32257	8.7117	0.387841	0.32369
F x O	6	522.62600	1226.3460	4.146903	69.53307
F x O x Y	6	0.72231	10.9596	17.450376	0.34520
F x B	2	575.56176	1020.3033	9.549965	29.65096
O x B	3	519.28550	1229.1983	12.167610	61.15638
F x O x B	6	226.15028	497.1034	5.512360	52.21792
B x Y	1	0.74759	1.6468	3.849622	0.47508
F x B x Y	2	1.56839	21.4511	14.085149	0.41880
O x B x Y	3	0.82376	6.5261	12.727484	0.18424
F x O x B x Y	6	0.43970	11.7485	8.746527	0.14398
Error	92	22.89815	33.3102	1.332306	1.96700

APPENDIX - XI

Analysis of variance (MSS) for zinc and copper content in wheat

Source of variation	d.f.	M.S.S.							
		Zinc content (mg kg^{-1})				Copper content (mg kg^{-1})			
		Grain		Straw		Grain		Straw	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	2.2930	4.78559	1.3483	1.40755	0.1687	0.19986	0.0840	0.06500
Fertility levels (F)	2	67.2722*	97.15804*	29.5973*	36.99140*	4.0604*	5.2481*	0.7116*	1.32942*
Organic sources (O)	3	36.7196*	23.98374*	15.8298*	10.13194*	1.5210*	1.48614*	0.5657*	0.52941*
Bio-inoculants (B)	1	125.8173*	25.78681*	41.5460*	14.63769*	7.2165*	1.78515*	2.9302*	0.70606*
F x O	6	17.7474	61.22790	7.3471	23.31220	2.3960	3.86672	0.3544	0.90333
F x B	2	55.6208	33.58804	17.1913	10.87250	1.4854	2.20187	0.1007	0.36598
O x B	3	35.9446	68.14283	11.4488	24.87630	1.5158	4.23859	0.2756	0.74956
F x O x B	6	11.2788	51.34124	4.7793	19.97914	0.9593	2.75765	0.2965	0.47677
Error	46	6.2017	4.72899	2.1303	1.76224	0.3850	0.30518	0.0666	0.08670

*Significant at 5% level of significance

APPENDIX - XII

Pooled analysis of variance (MSS) for zinc and copper content in wheat

Source of variation	d.f.	M.S.S.			
		Zinc content (mg kg^{-1})		Copper content (mg kg^{-1})	
		Grain	Straw	Grain	Straw
Year (Y)	1	28.768586	7.82453	1.673754	0.543355
Replication (R)	4	3.539315	1.37791	0.184290	0.074478
Fertility levels (F)	2	163.039823*	66.25109*	9.255542*	1.993171*
Organic sources (O)	3	59.604090*	25.57668*	2.965092*	1.092402*
Bio-inoculants (B)	1	132.761893*	52.75232*	8.090065*	3.256516*
F x Y	2	1.390414	0.33760	0.052981	0.047880
O x Y	3	1.099232	0.38502	0.042020	0.002663
F x O	6	17.611514	8.12198	1.343494	0.232339
F x O x Y	6	61.363831	22.53728	4.919249	1.025391
F x B	2	38.723571	11.81686	2.259386	0.408968
O x B	3	53.930308	16.96001	1.848331	0.163298
F x O x B	6	20.645792	8.14946	1.058440	0.272987
B x Y	1	18.842176	3.43141	0.911600	0.379776
F x B x Y	2	50.485249	16.24692	1.427893	0.057685
O x B x Y	3	50.157084	19.36507	3.906030	0.861911
F x O x B x Y	6	41.974272	16.60900	2.658509	0.500316
Error	92	5.465356	1.94629	0.345098	0.076670

APPENDIX - XIII

Analysis of variance (MSS) for nitrogen uptake by wheat

Source of variation	d.f.	M.S.S.					
		N uptake (kg ha^{-1})					
		Grain		Straw		Total	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	17.631	16.783	53.393	19.645	29.95	69.14
Fertility levels (F)	2	2170.897*	2732.709*	1019.172*	1342.886*	6164.82*	7906.90*
Organic sources (O)	3	1626.018*	1448.101*	346.791*	563.825*	3473.54*	3782.21*
Bio-inoculants (B)	1	1285.052*	1368.817*	420.751*	236.904*	3176.43*	2744.63*
F x O	6	35.083	231.767	258.652	670.512	272.80	1437.49
F x B	2	315.792	263.862	221.537	478.731	524.08	1044.16
O x B	3	385.083	701.413	71.774	385.813	618.77	2023.38
F x O x B	6	248.432	445.638	198.791	847.513	684.78	2298.49
Error	46	36.883	82.469	31.760	37.049	99.42	176.57

*Significant at 5% level of significance

APPENDIX - XIV

Pooled analysis of variance (MSS) for nitrogen uptake by wheat

Source of variation	**d.f.**	**M.S.S.**		
		N uptake (kg ha^{-1})		
		Grain	**Straw**	**Total**
Year (Y)	1	262.77045	234.30355	993.3322
Replication (R)	4	17.20695	36.51896	49.5444
Fertility levels (F)	2	4887.35683*	2350.91405*	14017.4977*
Organic sources (O)	3	3062.19703*	887.78910*	7233.3601*
Bio-inoculants (B)	1	2653.20787*	644.54482*	5913.1772*
F x Y	2	16.24932	11.14401	54.2193
O x Y	3	11.92256	22.82655	22.3859
F x O	6	134.93202	88.05487	394.3313
F x O x Y	6	131.91831	841.10862	1315.9548
F x B	2	549.51416	138.88619	1234.7925
O x B	3	954.63581	394.28009	2289.3879
F x O x B	6	589.92541	571.73153	2095.1913
B x Y	1	0.66115	13.10995	7.8829
F x B x Y	2	30.13957	561.38251	333.4441
O x B x Y	3	131.86095	63.30681	352.7631
F x O x B x Y	6	104.14431	474.57246	888.0765
Error	92	59.67606	34.40424	137.9946

APPENDIX - XV

Analysis of variance (MSS) for phosphorus uptake by wheat

Source of variation	d.f.	M.S.S.					
		P uptake (kg ha^{-1})					
		Grain		Straw		Total	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	0.0648	0.8056	4.3299	1.899	4.125	4.622
Fertility levels (F)	2	94.5233*	117.2273*	88.5775*	118.364*	366.085*	471.123*
Organic sources (O)	3	75.5876*	76.3094*	36.5669*	66.155*	217.068*	282.599*
Bio-inoculants (B)	1	54.6506*	85.6230*	34.9250*	39.234*	176.952*	240.776*
F x O	6	2.3058	6.6850	22.1405	57.678	20.891	89.006
F x B	2	12.7909	7.5930	25.5091	50.111	40.353	80.958
O x B	3	14.9894	34.6930	6.6308	30.599	26.952	124.392
F x O x B	6	11.1907	19.7076	18.6644	72.644	45.315	148.431
Error	46	2.2718	3.0660	2.5458	3.168	7.860	9.782

*Significant at 5% level of significance

APPENDIX - XVI

Pooled analysis of variance (MSS) for phosphorus uptake by wheat

Source of variation	d.f.	M.S.S.		
		P uptake (kg ha^{-1})		
		Grain	Straw	Total
Year (Y)	1	26.31096	33.25187	118.7199
Replication (R)	4	0.43520	3.11422	4.3735
Fertility levels (F)	2	211.13315*	205.86255*	833.8872*
Organic sources (O)	3	150.82290*	99.87859*	495.6770*
Bio-inoculants (B)	1	138.54260*	74.09627*	415.2764*
F x Y	2	0.61750	1.07858	3.3211
O x Y	3	1.07405	2.84345	3.9892
F x O	6	4.87612	9.00770	24.5484
F x O x Y	6	4.11474	70.81102	85.3478
F x B	2	20.04705	10.32834	58.8631
O x B	3	42.41965	32.45956	129.5172
F x O x B	6	24.70689	47.67040	122.3050
B x Y	1	1.73104	0.06264	2.4523
F x B x Y	2	0.33694	65.29186	62.4483
O x B x Y	3	7.26280	4.76991	21.8266
F x O x B x Y	6	6.19138	43.63756	71.4410
Error	92	2.66888	2.85679	8.8207

APPENDIX - XVII

Analysis of variance (MSS) for potassium uptake by wheat

Source of variation	**d.f.**	**M.S.S.**					
		K uptake (kg ha^{-1})					
		Grain		**Straw**		**Total**	
		2015-16	**2016-17**	**2015-16**	**2016-17**	**2015-16**	**2016-17**
Replication (R)	2	1.883	2.495	119.62	30.191	94.49	47.27
Fertility levels (F)	2	209.916*	152.950*	5816.09*	7380.479*	8235.69*	9636.60*
Organic sources (O)	3	219.703*	68.004*	3367.34*	4874.525*	5301.55*	6071.45*
Bio-inoculants (B)	1	140.294*	166.704*	2617.32*	3317.458*	3969.55*	4971.49*
F x O	6	5.581	51.359	2207.98	1034.747	2165.15	937.94
F x B	2	27.598	81.315	1345.88	490.764	1216.41	622.79
O x B	3	38.707	38.868	395.04	252.787	443.02	259.52
F x O x B	6	29.755	53.357	1409.50	2643.219	1625.31	2998.05
Error	46	3.894	8.613	105.20	143.235	119.53	179.55

*Significant at 5% level of significance

APPENDIX - XVIII

Pooled analysis of variance (MSS) for potassium uptake by wheat

Source of variation	**d.f.**	**M.S.S.**		
		K uptake (kg ha^{-1})		
		Grain	**Straw**	**Total**
Year (Y)	1	8.57946	519.00	661.036
Replication (R)	4	2.18905	74.90	70.880
Fertility levels (F)	2	360.18297*	13138.18*	17836.036*
Organic sources (O)	3	265.22232*	8116.00*	11311.861*
Bio-inoculants (B)	1	306.42848*	5914.06*	8912.873*
F x Y	2	2.68334	58.39	36.252
O x Y	3	22.48463	125.87	61.143
F x O	6	25.11016	844.70	1109.147
F x O x Y	6	31.83042	2398.02	1993.943
F x B	2	55.37691	668.94	1086.267
O x B	3	68.11465	574.57	604.084
F x O x B	6	67.07458	2842.85	3595.478
B x Y	1	0.56906	20.72	28.158
F x B x Y	2	53.53560	1167.70	752.931
O x B x Y	3	9.46027	73.27	98.447
F x O x B x Y	6	16.03715	1209.86	1027.879
Error	92	6.25381	124.22	149.537

APPENDIX - XIX

Analysis of variance (MSS) for iron uptake by wheat

Source of variation	d.f.	M.S.S.					
		Fe uptake (g ha^{-1})					
		Grain		Straw		Total	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	554.09	1005.18	24121.9	716.94	21211.96	2903.34
Fertility levels (F)	2	54086.42*	65862.83*	458773.0*	566160.55*	827893.56*	1016163.60*
Organic sources (O)	3	65708.38*	60302.26*	331396.7*	430004.71*	691760.56*	801720.02*
Bio-inoculants (B)	1	26118.44*	27302.39*	148361.4*	230517.81*	298978.38*	416485.72*
F x O	6	3060.41	16481.79	234983.9	104449.30	243249.76	70269.22
F x B	2	12699.34	25480.82	91999.1	84058.14	86890.03	103650.16
O x B	3	13531.99	7574.47	24819.2	11020.38	37498.87	28900.08
F x O x B	6	7069.78	10685.06	114733.3	228153.31	139976.32	236595.55
Error	46	1114.22	2786.88	9161.0	12486.39	10917.92	18457.06

*Significant at 5% level of significance

APPENDIX - XX

Pooled analysis of variance (MSS) for iron uptake by wheat

Source of variation	**d.f.**	**M.S.S.**		
		Fe uptake (g ha^{-1})		
		Grain	**Straw**	**Total**
Year (Y)	1	14483.78	44078.28	109096.01
Replication (R)	4	779.64	12419.40	12057.65
Fertility levels (F)	2	119654.89*	1020374.37*	1837671.51*
Organic sources (O)	3	125228.35*	751958.39*	1487549.15*
Bio-inoculants (B)	1	53414.27*	374371.93*	710606.29*
F x Y	2	294.36	4559.21	6385.65
O x Y	3	782.30	9442.99	5931.43
F x O	6	7892.13	100732.99	150363.49
F x O x Y	6	11650.07	238700.26	163155.49
F x B	2	16401.81	72527.01	157736.19
O x B	3	20162.90	26389.69	60120.41
F x O x B	6	12812.72	225557.93	283298.88
B x Y	1	6.56	4507.33	4857.81
F x B x Y	2	21778.35	103530.27	32804.00
O x B x Y	3	943.55	9449.90	6278.54
F x O x B x Y	6	4942.12	117328.69	93272.98
Error	92	1950.55	10823.67	14687.49

APPENDIX - XXI

Analysis of variance (MSS) for manganese uptake by wheat

Source of variation	d.f.	M.S.S.					
		Mn uptake (g ha^{-1})					
		Grain		Straw		Total	
		2015-16	**2016-17**	**2015-16**	**2016-17**	**2015-16**	**2016-17**
Replication (R)	2	14.936	13.111	1201.34	101.288	970.75	154.48
Fertility levels (F)	2	2071.527*	2757.295*	15718.42*	21125.061*	29153.42*	39114.62*
Organic sources (O)	3	1679.558*	1529.923*	5273.58*	10299.550*	12879.46*	19576.78*
Bio-inoculants (B)	1	1529.823*	1227.387*	2650.33*	2921.844*	8207.33*	7936.70*
F x O	6	144.473	154.387	1761.33	11133.143	2485.48	12854.44
F x B	2	194.908	219.851	943.21	5389.380	1792.29	6235.22
O x B	3	441.220	758.583	7737.81	5625.077	8689.18	10082.54
F x O x B	6	167.771	331.634	2328.70	12783.854	3293.79	16194.60
Error	46	35.523	76.984	335.00	585.776	452.39	885.16

*Significant at 5% level of significance

APPENDIX - XXII

Pooled analysis of variance (MSS) for manganese uptake by wheat

Source of variation	d.f.	M.S.S.		
		Mn uptake (g ha^{-1})		
		Grain	Straw	Total
Year (Y)	1	444.5951	8679.493	13052.88
Replication (R)	4	14.0233	651.314	562.61
Fertility levels (F)	2	4803.8667*	36622.854*	67874.76*
Organic sources (O)	3	3189.2655*	15019.027*	31868.44*
Bio-inoculants (B)	1	2748.8908*	5568.865*	16142.90*
F x Y	2	24.9550	220.628	393.28
O x Y	3	20.2150	554.106	587.80
F x O	6	181.0166	7423.202	9304.58
F x O x Y	6	117.8436	5471.268	6035.35
F x B	2	381.9962	3515.561	5764.58
O x B	3	957.5833	13184.154	18739.97
F x O x B	6	413.4822	12432.820	16165.19
B x Y	1	8.3186	3.309	1.13
F x B x Y	2	32.7620	2817.028	2262.93
O x B x Y	3	242.2199	178.737	31.75
F x O x B x Y	6	85.9222	2679.731	3323.20
Error	92	56.2534	460.388	668.78

APPENDIX - XXIII

Analysis of variance (MSS) for zinc uptake by wheat

Source of variation	d.f.	M.S.S.					
		Zn uptake (g ha^{-1})					
		Grain		Straw		Total	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	15.36	31.74	544.08	90.778	524.51	172.76
Fertility levels (F)	2	8022.90*	10779.21*	11384.30*	15558.558*	38521.08*	52221.00*
Organic sources (O)	3	6914.72*	5919.06*	5405.01*	6900.374*	24498.54*	25387.09*
Bio-inoculants (B)	1	6301.98*	4668.48*	5800.88*	2783.531*	24195.36*	14661.69*
F x O	6	552.51	619.66	3202.01	6724.957	3868.41	9693.62
F x B	2	790.54	924.44	2790.96	3822.492	3371.84	5374.39
O x B	3	1744.21	3111.76	493.89	4479.205	2806.67	14140.21
F x O x B	6	722.44	1343.84	2068.21	8874.811	3751.62	15250.81
Error	46	190.38	313.47	269.07	407.514	680.02	1076.26

*Significant at 5% level of significance

APPENDIX - XXIV

Pooled analysis of variance (MSS) for zinc uptake by wheat

Source of variation	**d.f.**	**M.S.S.**		
		Zn uptake (g ha^{-1})		
		Grain	**Straw**	**Total**
Year (Y)	1	1804.266	2935.274	9342.154
Replication (R)	4	23.547	317.427	348.636
Fertility levels (F)	2	18697.428*	26779.392*	90221.267*
Organic sources (O)	3	12769.871*	12156.462*	49805.800*
Bio-inoculants (B)	1	10909.316*	8310.533*	38263.194*
F x Y	2	104.675	163.467	520.813
O x Y	3	63.909	148.927	79.830
F x O	6	755.474	1293.156	3643.749
F x O x Y	6	416.700	8633.809	9918.274
F x B	2	1532.776	932.814	4847.603
O x B	3	3920.555	3970.560	13311.056
F x O x B	6	1609.011	5311.201	10746.963
B x Y	1	61.148	273.882	593.854
F x B x Y	2	182.198	5680.638	3898.630
O x B x Y	3	935.407	1002.537	3635.825
F x O x B x Y	6	457.270	5631.824	8255.466
Error	92	251.926	338.291	878.142

APPENDIX - XXV

Analysis of variance (MSS) for copper uptake by wheat

Source of variation	d.f.	M.S.S.					
		Cu uptake (g ha^{-1})					
		Grain		Straw		Total	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	3.7417	0.78525	1.789	5.113	8.37	3.521
Fertility levels (F)	2	485.2348*	625.92697*	341.873*	567.239*	1640.95*	2384.381*
Organic sources (O)	3	379.5562*	360.57747*	194.701*	296.159*	1107.27*	1292.293*
Bio-inoculants (B)	1	377.9610*	293.26644*	370.248*	126.212*	1496.38*	804.258*
F x O	6	55.1554	37.95182	129.818	275.927	231.45	426.076
F x B	2	80.1498	64.29888	11.126	135.572	80.37	227.379
O x B	3	60.0579	192.23952	14.190	138.181	34.69	609.417
F x O x B	6	45.6136	76.39147	94.078	281.070	206.95	559.401
Error	46	9.7733	18.69561	7.922	16.615	24.66	50.924

*Significant at 5% level of significance

APPENDIX - XXVI

Pooled analysis of variance (MSS) for copper uptake by wheat

Source of variation	**d.f.**	**M.S.S.**		
		Cu uptake (g ha^{-1})		
		Grain	**Straw**	**Total**
Year (Y)	1	111.893	151.1059	523.0583
Replication (R)	4	2.263	3.4508	5.9472
Fertility levels (F)	2	1106.670*	894.8170*	3990.5215*
Organic sources (O)	3	735.490*	481.7491*	2392.0739*
Bio-inoculants (B)	1	668.545*	464.4010*	2247.3483*
F x Y	2	4.491	14.2958	34.8114
O x Y	3	4.644	9.1113	7.4841
F x O	6	54.096	51.1125	166.1791
F x O x Y	6	39.011	354.6320	491.3452
F x B	2	105.761	53.9885	287.3542
O x B	3	185.143	107.2039	427.9503
F x O x B	6	88.868	191.3959	451.3391
B x Y	1	2.682	32.0594	53.2885
F x B x Y	2	38.688	92.7096	20.3942
O x B x Y	3	67.155	45.1671	216.1560
F x O x B x Y	6	33.137	183.7520	315.0155
Error	92	14.234	12.2682	37.7933

Appendix - XXVII

Analysis of variance (MSS) for bulk density, particle density, porosity and water holding capacity of soil

Source of variation	d.f.	M.S.S.							
		Bulk density ($Mg\ m^{-3}$)		Particle density ($Mg\ m^{-3}$)		Porosity (%)		Water holding capacity (%)	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	0.0055	0.01188	0.0037	0.02366	3.2628	0.78661	0.3237	1.26494
Fertility levels (F)	2	0.0032	0.00191	0.0050	0.00451	0.5676	0.23145	79.9310*	75.76895*
Organic sources (O)	3	0.0091	0.00478	0.0396	0.02767	0.6429	1.38010	60.9500*	65.46719*
Bio-inoculants (B)	1	0.0026	0.00127	0.0046	0.00174	0.1156	0.30845	32.7423*	18.99460*
F x O	6	0.0072	0.00337	0.0365	0.00637	2.7530	1.30310	127.1936	126.34285
F x B	2	0.0001	0.00024	0.0036	0.00029	1.0029	0.07746	134.4694	168.00151
O x B	3	0.0185	0.00314	0.0542	0.00648	0.3666	1.27744	40.7423	35.17555
F x O x B	6	0.0070	0.02519	0.0278	0.08057	2.2486	1.35443	41.8003	53.69518
Error	46	0.0011	0.00060	0.0046	0.00277	0.8963	0.93475	3.0741	3.54050

*Significant at 5% level of significance

APPENDIX - XXVIII

Pooled analysis of variance (MSS) for bulk density, particle density, porosity and water holding capacity of soil

Source of variation	d.f.	M.S.S.			
		Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Porosity (%)	Water holding capacity (%)
Year (Y)	1	0.0154331	0.012177	5.712745	208.1406
Replication (R)	4	0.0086746	0.013672	2.024706	0.7943
Fertility levels (F)	2	0.0049943	0.009527	0.624173	155.5702*
Organic sources (O)	3	0.0133963	0.065578	1.567773	125.9501*
Bio-inoculants (B)	1	0.0037528	0.006019	0.400892	50.8069*
F x Y	2	0.0001392	0.000007	0.174872	0.1298
O x Y	3	0.0004855	0.001655	0.455253	0.4671
F x O	6	0.0043278	0.019304	2.505087	252.9519
F x O x Y	6	0.0062351	0.023546	1.550988	0.5845
F x B	2	0.0003587	0.002873	0.323816	301.5086
O x B	3	0.0073499	0.031182	0.582102	75.6668
F x O x B	6	0.0198880	0.065818	1.696674	94.5059
B x Y	1	0.0001195	0.000345	0.023186	0.9300
F x B x Y	2	0.0000189	0.001021	0.756497	0.9624
O x B x Y	3	0.0142666	0.029448	1.061911	0.2511
F x O x B x Y	6	0.0123056	0.042557	1.906354	0.9896
Error	92	0.0008690	0.003690	0.915525	3.3073

APPENDIX - XXIX

Analysis of variance (MSS) for pH, EC and organic carbon content in soil

Source of variation	**d.f.**	**M.S.S.**					
		pH		**EC (dSm^{-1})**		**Organic carbon (%)**	
		2015-16	**2016-17**	**2015-16**	**2016-17**	**2015-16**	**2016-17**
Replication (R)	2	0.4027	0.18818	0.0014	0.00093	0.0009	0.00082
Fertility levels (F)	2	0.0155	0.01471	0.0006	0.00039	0.0314*	0.02332*
Organic sources (O)	3	0.2632	0.23539	0.0005	0.00198	0.0174*	0.01484*
Bio-inoculants (B)	1	0.0021	0.01526	0.0015	0.00083	0.0045	0.00040
F x O	6	0.9792	0.88880	0.0027	0.00165	0.0138	0.00991
F x B	2	0.0616	0.14497	0.0003	0.00095	0.0002	0.00128
O x B	3	0.5317	0.53703	0.0009	0.00117	0.0013	0.00678
F x O x B	6	0.0665	0.06099	0.0006	0.00039	0.0014	0.00954
Error	46	0.1731	0.19479	0.0008	0.00091	0.0020	0.00073

*Significant at 5% level of significance

APPENDIX - XXX

Pooled analysis of variance (MSS) for pH, EC and organic carbon content in soil

Source of variation	**d.f.**	**M.S.S.**		
		pH	**EC (dSm^{-1})**	**Organic carbon (%)**
Year (Y)	1	0.55481	0.01424	0.05644
Replication (R)	4	0.29546	0.00116	0.00086
Fertility levels (F)	2	0.03000	0.00015	0.05443*
Organic sources (O)	3	0.49564	0.00226	0.03214*
Bio-inoculants (B)	1	0.01429	0.00223	0.00378
F x Y	2	0.00024	0.00083	0.00032
O x Y	3	0.00291	0.00026	0.00007
F x O	6	1.85684	0.00392	0.01771
F x O x Y	6	0.01113	0.00040	0.00603
F x B	2	0.19338	0.00093	0.00123
O x B	3	1.05742	0.00165	0.00232
F x O x B	6	0.11936	0.00054	0.00497
B x Y	1	0.00305	0.00004	0.00110
F x B x Y	2	0.01317	0.00028	0.00024
O x B x Y	3	0.01126	0.00043	0.00573
F x O x B x Y	6	0.00810	0.00042	0.00597
Error	92	0.18393	0.00084	0.00135

APPENDIX - XXXI

Analysis of variance (MSS) for available N, P and K in soil after harvest of crop

Source of variation	d.f.	M.S.S.					
		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	380.47	20.11	3.3631	0.0004	29.53	27.527
Fertility levels (F)	2	2834.89*	2958.73*	24.2092*	26.8244*	3498.27*	4352.902*
Organic sources (O)	3	3524.03*	6997.65*	30.3351*	41.9968*	4095.19*	5211.536*
Bio-inoculants (B)	1	1160.63*	1734.31*	12.3607*	14.1066*	1334.04*	1162.008*
F x O	6	6349.64	14056.81	37.7743	84.9830	4550.14	12448.009
F x B	2	2669.32	1812.11	18.0150	16.2970	2318.71	3059.336
O x B	3	10178.82	9861.89	57.2776	71.1297	10302.50	11738.192
F x O x B	6	4691.00	10906.15	31.5995	72.3340	5101.77	11205.634
Error	46	262.17	389.41	2.5177	2.4787	159.15	160.774

*Significant at 5% level of significance

APPENDIX - XXXII

Pooled analysis of variance (MSS) for available N, P and K in soil after harvest of crop

Source of variation	**d.f.**	**M.S.S.**		
		Available N (kg ha^{-1})	**Available P (kg ha^{-1})**	**Available K (kg ha^{-1})**
Year (Y)	1	871.442	75.12631	462.5791
Replication (R)	4	200.291	1.68176	28.5283
Fertility levels (F)	2	5765.910*	50.66966*	7825.6723*
Organic sources (O)	3	9936.190*	71.35114*	9247.6620*
Bio-inoculants (B)	1	2866.230*	26.43840*	2493.0815*
F x Y	2	27.710	0.36403	25.4953
O x Y	3	585.492	0.98074	59.0627
F x O	6	3814.761	26.18468	2931.2476
F x O x Y	6	16591.685	96.57268	14066.8974
F x B	2	1983.198	15.17331	2280.7178
O x B	3	16587.135	104.31244	17799.3118
F x O x B	6	7108.500	55.14944	8719.9407
B x Y	1	28.706	0.02882	2.9678
F x B x Y	2	2498.232	19.13868	3097.3309
O x B x Y	3	3453.578	24.09481	4241.3771
F x O x B x Y	6	8488.642	48.78405	7587.4624
Error	92	325.789	2.49816	159.9628

APPENDIX - XXXIII

Analysis of variance (MSS) for available Fe, Mn, Zn and Cu in soil after harvest of crop

Source of variation	d.f.	M.S.S.							
		Available Fe (mg kg^{-1})		Available Mn (mg kg^{-1})		Available Zn (mg kg^{-1})		Available Cu (mg kg^{-1})	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	0.0151	0.00379	0.1296	0.01865	0.0073	0.00110	0.0061	0.00065
Fertility levels (F)	2	0.3438*	0.25963*	3.0762*	1.40434*	0.1536*	0.09773*	0.0658*	0.05783*
Organic sources (O)	3	0.3657*	0.68897*	3.6359*	6.86265*	0.1723*	0.39314*	0.0958*	0.23263*
Bio-inoculants (B)	1	0.0747	0.11144	0.5982	0.37517	0.0114	0.04497	0.0045	0.02661
F x O	6	0.5451	1.36008	5.4450	16.63076	0.3246	1.01959	0.1936	0.60331
F x B	2	0.2169	0.18278	2.0377	2.02232	0.1227	0.08828	0.0570	0.05224
O x B	3	0.9611	0.82912	16.7523	12.27111	1.2255	0.78279	0.7502	0.46319
F x O x B	6	0.5049	1.14353	6.5185	13.37262	0.4216	0.87436	0.2445	0.51737
Error	46	0.0529	0.04110	0.2308	0.30006	0.0174	0.01948	0.0145	0.01153

*Significant at 5% level of significance

APPENDIX - XXXIV

Pooled analysis of variance (MSS) for available Fe, Mn, Zn and Cu in soil after harvest of crop

Source of variation	**d.f.**	**M.S.S.**			
		Available Fe (mg kg^{-1})	**Available Mn (mg kg^{-1})**	**Available Zn (mg kg^{-1})**	**Available Cu (mg kg^{-1})**
Year (Y)	1	0.15374	1.0255	0.05457	0.02859
Replication (R)	4	0.00942	0.0741	0.00422	0.00340
Fertility levels (F)	2	0.59970*	4.2709*	0.24813*	0.12347*
Organic sources (O)	3	1.00420*	10.1495*	0.54151*	0.31231*
Bio-inoculants (B)	1	0.18431	0.9604	0.05082	0.02650
F x Y	2	0.00376	0.2097	0.00325	0.00013
O x Y	3	0.05050	0.3490	0.02391	0.01615
F x O	6	0.42344	4.4401	0.26174	0.15300
F x O x Y	6	1.48175	17.6357	1.08242	0.64388
F x B	2	0.15741	0.9197	0.03407	0.01220
O x B	3	1.45779	23.8104	1.63355	0.98406
F x O x B	6	0.78925	8.4358	0.51577	0.28537
B x Y	1	0.00183	0.0129	0.00554	0.00461
F x B x Y	2	0.24231	3.1403	0.17691	0.09708
O x B x Y	3	0.33238	5.2130	0.37476	0.22933
F x O x B x Y	6	0.85917	11.4553	0.78018	0.47646
Error	92	0.04698	1.0255	0.01846	0.01299

APPENDIX - XXXV

Analysis of variance (MSS) for dehydrogenase activity, bacteria and fungi population in soil after harvest of crop

Source of variation	d.f.	M.S.S.					
		Dehydrogenase activity (µg TPF g^{-1} soil)		Bacteria population (10^5 CFU g^{-1})		Fungi population (10^4 CFU g^{-1})	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication (R)	2	0.0251	0.01664	0.2478	0.32528	0.6300	0.13847
Fertility levels (F)	2	0.2312*	0.32047*	24.7170*	10.53766*	19.2858*	10.10708*
Organic sources (O)	3	0.4058*	0.50439*	24.2442*	16.93350*	24.1577*	24.75187*
Bio-inoculants (B)	1	0.2200*	0.39851*	7.2956*	7.41422*	9.3305*	10.07608*
F x O	6	2.0660	3.81677	24.5119	93.71033	37.3884	88.12245
F x B	2	0.5936	0.67615	19.5232	10.55992	21.7480	22.72796
O x B	3	1.9582	3.62179	7.4542	74.18110	4.9935	50.30801
F x O x B	6	1.8680	1.84843	16.3980	34.04935	12.7856	28.33834
Error	46	0.0437	0.06988	0.6468	0.93061	0.7609	0.66037

*Significant at 5% level of significance

APPENDIX - XXXVI

Pooled analysis of variance (MSS) for dehydrogenase activity, bacteria and fungi population in soil after harvest of crop

Source of variation	d.f.	M.S.S.		
		Dehydrogenase activity (μg TPF g^{-1} soil)	**Bacteria population (10^5 CFU g^{-1})**	**Fungi population (10^4 CFU g^{-1})**
Year (Y)	1	0.446451	9.14967	31.2370
Replication (R)	4	0.020864	0.28653	0.3842
Fertility levels (F)	2	0.547980*	33.71961*	28.6510*
Organic sources (O)	3	0.903812*	40.62726*	48.5593*
Bio-inoculants (B)	1	0.605329*	14.70958*	19.3994*
F x Y	2	0.003708	1.53502	0.7419
O x Y	3	0.006420	0.55045	0.3503
F x O	6	0.937613	33.22675	41.8114
F x O x Y	6	4.945146	84.99548	83.6995
F x B	2	0.594442	27.77571	43.5849
O x B	3	5.200971	50.32386	33.2881
F x O x B	6	1.722400	16.63313	12.2213
B x Y	1	0.013164	0.00024	0.0072
F x B x Y	2	0.675315	2.30743	0.8911
O x B x Y	3	0.378977	31.31145	22.0135
F x O x B x Y	6	1.994009	33.81418	28.9026
Error	92	0.056800	0.78868	0.7106

APPENDIX - XXXVII

Analysis of variance (MSS) for dehydrogenase activity, bacteria and fungi population in soil after harvest of crop

Source of variation	d.f.	M.S.S.			
		Net Return (₹ ha^{-1})		Benefit cost ratio	
		2015-16	2016-17	2015-16	2016-17
Replication (R)	2	1866964.5	25726002.2	0.0009	0.01467
Fertility levels (F)	2	1444577121.1*	1815269834.3*	0.3903*	0.46392*
Organic sources (O)	3	188991116.4*	258427563.6*	0.3079*	0.44395*
Bio-inoculants (B)	1	677113675.4*	942292676.2*	0.2683*	0.36605*
F x O	6	199467597.6	96028159.7	0.0938	0.04602
F x B	2	312318679.9	145994351.8	0.1157	0.06421
O x B	3	352578142.1	188412945.3	0.1764	0.09923
F x O x B	6	241879238.5	218111532.6	0.0899	0.07628
Error	46	48861387.2	68763381.0	0.0165	0.02671

*Significant at 5% level of significance

APPENDIX - XXXVIII

Pooled analysis of variance (MSS) for dehydrogenase activity, bacteria and fungi population in soil after harvest of crop

Source of variation	d.f.	M.S.S.	
		Net Return (₹ ha^{-1})	**Benefit cost ratio**
Year (Y)	1	202493811	0.085947
Replication (R)	4	13796483.33	0.007805
Fertility levels (F)	2	3249251764*	0.852649*
Organic sources (O)	3	432049760.4*	0.743035*
Bio-inoculants (B)	1	1608476772*	0.630589*
F x Y	2	10595191.14	0.001613
O x Y	3	15368919.57	0.008839
F x O	6	131111325.4	0.078834
F x O x Y	6	164384431.9	0.060962
F x B	2	160227507.2	0.068774
O x B	3	518781837.4	0.267068
F x O x B	6	354340102.7	0.121380
B x Y	1	10929580.04	0.003787
F x B x Y	2	298085524.5	0.111087
O x B x Y	3	22209250	0.008537
F x O x B x Y	6	105650668.4	0.044843
Error	92	58812384.11	0.021595

APPENDIX - XXXIX

Common cost of cultivation of wheat excluding treatment cost during 2015-16 and 2016-17

S. No.	Particulars of operation	Cost (₹ ha^{-1})	Inputs	Rate/unit (₹)
1.	Disc ploughing	1200	Disc ploughing	1200 ha^{-1}
2.	Pre sowing irrigation	700	Harrowing	600 ha^{-1}
3.	Harrowing	600	Planking	500 ha^{-1}
4.	Planking	200	Labour	200 day^{-1}
5.	Seed bed preparation (8 labour)	1600	Seed	50 kg^{-1}
6.	Sowing of seeds (8 labour)	1600	Irrigation	700 ha^{-1}
7.	Cost of seed (100 kg ha-1)	5000		
8.	Irrigation (6)	4200		
9.	Weeding, hoeing and thinning (15 labour)	3000		
10.	Harvesting of crops (15 labour)	3000		
11.	Threshing and winnowing (15 labour)	3000		
12.	Miscellaneous	400		
13.	Total	24500		

APPENDIX - XXXX

Comparative economics of various treatment combinations for wheat, 2015-16

S. No.	Treatment combinations	Common cost of cultivation (₹ ha^{-1})	Treatment cost (₹ ha^{-1})	Total cost (₹ ha^{-1})	Wheat yield ($kg\ ha^{-1}$)		Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
					Seed	Straw			
1.	A1B1C1	24500	17630	42130	3094	7192	80868	38738	1.92
2.	A1B1C2	24500	17880	42380	3305	7216	84742	42362	2.00
3.	A1B2C1	24500	30730	55230	5097	7125	116684	61454	2.11
4.	A1B2C2	24500	30980	55480	4345	9283	110707	55227	2.00
5.	A1B3C1	24500	17330	41830	2856	7301	76953	35123	1.84
6.	A1B3C2	24500	17580	42080	4396	7389	104982	62902	2.49
7.	A1B4C1	24500	30130	54630	4077	9019	104945	50315	1.92
8.	A1B4C2	24500	30380	54880	4441	9040	111582	56702	2.03
9.	A2B1C1	24500	19395	43895	3978	8881	102692	58797	2.34
10.	A2B1C2	24500	19645	44145	3872	8931	100947	56802	2.29
11.	A2B2C1	24500	32495	56995	4330	8961	109300	52305	1.92
12.	A2B2C2	24500	32745	57245	4732	10063	120406	63161	2.10
13.	A2B3C1	24500	19095	43595	4520	6915	105563	61968	2.42
14.	A2B3C2	24500	19345	43845	4459	8296	109304	65459	2.49
15.	A2B4C1	24500	31895	56395	5665	9746	136077	79682	2.41
16.	A2B4C2	24500	32145	56645	4521	10116	116785	60140	2.06
17.	A3B1C1	24500	21159	45659	4474	10451	117119	71460	2.57
18.	A3B1C2	24500	21409	45909	4835	6644	110286	64377	2.40
19.	A3B2C1	24500	34259	58759	4285	9412	110066	51307	1.87
20.	A3B2C2	24500	34509	59009	5469	9898	133079	74070	2.26
21.	A3B3C1	24500	20859	45359	3505	9891	97707	52348	2.15
22.	A3B3C2	24500	21109	45609	4588	10275	118550	72941	2.60
23.	A3B4C1	24500	33659	58159	5031	7859	118058	59899	2.03
24.	A3B4C2	24500	33909	58409	5397	9747	131263	72854	2.25

Sale price of wheat grain ₹ 16000 t^{-1} and straw ₹ 3500 t^{-1}

APPENDIX - XXXXI

Comparative economics of various treatment combinations for wheat, 2016-17

S. No.	Treatment combinations	Common cost of cultivation (₹ ha^{-1})	Treatment cost (₹ ha^{-1})	Total cost (₹ ha^{-1})	Wheat yield ($kg\ ha^{-1}$)		Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
					Seed	Straw			
1.	A1B1C1	24500	17630	42130	3575	6188	86010	43880	2.04
2.	A1B1C2	24500	17880	42380	3111	8076	84267	41887	1.99
3.	A1B2C1	24500	30730	55230	3664	10194	101637	46407	1.84
4.	A1B2C2	24500	30980	55480	4441	8024	108022	52542	1.95
5.	A1B3C1	24500	17330	41830	3169	8711	87532	45702	2.09
6.	A1B3C2	24500	17580	42080	4406	7791	106583	64503	2.53
7.	A1B4C1	24500	30130	54630	4415	6153	100998	46368	1.85
8.	A1B4C2	24500	30380	54880	5316	8883	126772	71892	2.31
9.	A2B1C1	24500	19395	43895	4010	9290	104698	60803	2.39
10.	A2B1C2	24500	19645	44145	4593	7743	109777	65632	2.49
11.	A2B2C1	24500	32495	56995	4942	7993	116926	59931	2.05
12.	A2B2C2	24500	32745	57245	5423	10465	134242	76997	2.35
13.	A2B3C1	24500	19095	43595	3523	9040	95056	51461	2.18
14.	A2B3C2	24500	19345	43845	4609	9585	116516	72671	2.66
15.	A2B4C1	24500	31895	56395	5012	11330	129873	73478	2.30
16.	A2B4C2	24500	32145	56645	4836	8375	116362	59717	2.05
17.	A3B1C1	24500	21159	45659	4242	10282	112337	66678	2.46
18.	A3B1C2	24500	21409	45909	4417	8337	108681	62772	2.37
19.	A3B2C1	24500	34259	58759	5174	7903	120785	62026	2.06
20.	A3B2C2	24500	34509	59009	4848	10937	125538	66529	2.13
21.	A3B3C1	24500	20859	45359	4992	6676	113218	67859	2.50
22.	A3B3C2	24500	21109	45609	4918	8510	118300	72691	2.59
23.	A3B4C1	24500	33659	58159	5070	10728	128811	70652	2.21
24.	A3B4C2	24500	33909	58409	4946	12461	132643	74234	2.27

Sale price of wheat grain ₹ 16000 t^{-1} and straw ₹ 3500 t^{-1}