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Sustainable Improvement of Wheat (Triticum Aestivum L.) Yield Through Soil Amendments with Probiotic and Organic Manures

Hossain, Md. Anwar
University of Rajshahi

SUSTAINABLE IMPROVEMENT OF WHEAT (*TRITICUM AESTIVUM* L.) YIELD THROUGH SOIL AMENDMENTS WITH PROBIOTIC AND ORGANIC MANURES

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MD. ANWAR HOSSAIN
B. Sc. Ag., MS (AGRONOMY)

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PLANT BIOTECHNOLOGY AND GENETIC ENGINEERING LABORATORY
INSTITUTE OF BIOLOGICAL SCIENCES
UNIVERSITY OF RAJSHAHI
RAJSHAHI-6205
BANGLADESH

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To My

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DECLARATION

I hereby declare that the research work embodied in this thesis entitled **"SUSTAINABLE IMPROVEMENT OF WHEAT (*TRITICUM AESTIVUM* L.) YIELD THROUGH SOIL AMENDMENTS WITH PROBIOTIC AND ORGANIC MANURES"** has been carried out by me for the degree of Doctor of Philosophy under the guidance of **Professor Dr. S. M. Shahinul Islam** (Principal Supervisor), Institute of Biological Sciences, University of Rajshahi and **Professor Dr. Md. Mahmodol Hasan** (Co-supervisor), Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh.

I also declare that the result presented in this dissertation is my own investigation and any part of this thesis work has not been submitted to elsewhere for any degree/diploma or for similar purpose.

May 2021

Md. Anwar Hossain
PhD Fellow
Roll No. P-532
Session: 2016-2017
Institute of Biological Sciences
University of Rajshahi
Rajshahi-6205
Bangladesh

CERTIFICATE

This is to certify that **Md. Anwar Hossain** worked under our supervision as a PhD Fellow, Roll No: P-532, Session: 2016-2017, Institute of Biological Sciences, University of Rajshahi, Bangladesh. It is our great pleasure to forward his thesis entitled **"SUSTAINABLE IMPROVEMENT OF WHEAT (*TRITICUM AESTIVUM* L.) YIELD THROUGH SOIL AMENDMENTS WITH PROBIOTIC AND ORGANIC MANURES"** which is a genuine record of research carried out at Plant Biotechnology and Genetic Engineering Laboratory, Institute of Biological Sciences and its experimental field and in the Plant Pathology Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh.

This work is original and has not been submitted so far in part or in full, for the award of any degree or diploma by any other institute in home or abroad. Md. Anwar Hossain has fulfilled all the requirements for submission of the thesis for the award of the degree of **Doctor of Philosophy.**

Principal Supervisor

Dr. S. M. Shahinul Islam
Professor
Institute of Biological Sciences
University of Rajshahi
Rajshahi-6205, Bangladesh
Phone: +88-01715-209907
E-mail: shahinul68@gmail.com

Co-Supervisor

Dr. Md. Mahmodol Hasan
Professor
Dept. of Agronomy and Agricultural Extn.
University of Rajshahi
Rajshahi-6205, Bangladesh
Phone: +88-01739-824746
E-mail: mahmudul742001@yahoo.com

CONTENTS

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The Author

ABSTRACT

The present research work was conducted at Plant Biotechnology and Genetic Engineering Laboratory and the experimental field under Institute of Biological Sciences (IBSc), Rajshahi University and Plant Pathology Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh during the period from July 2016 to June 2019 to study the sustainable improvement of wheat (*Triticum aestivum* L.) yield through soil amendments with probiotic and organic manures. The treatments used in the research consisted of two factors i.e. **factor-A** (wheat varieties) *viz*. BARI wheat-28 (V_1), BARI wheat-29 (V_2), BARI wheat-30 (V_3) and **factor-B** (soil amendments) *viz*. Rice straw + vermicompost + green manure (T_1), Cow dung + vermicompost + green manure (T_2), Compost + vermicompost + green manure (T_3), Poultry manure + vermicompost + green manure (T_4), *Trichoderma harzianum* + vermicompost + green manure (T_5), Mung bean residue + vermicompost + green manure (T_6), *Trichoderma viride* + vermicompost + green manure (T_7), Chemical fertilizer (T_8) and Control (T_0). *Sesbania rostrata* was produced as green manure crop in this study. The experiment was designed as randomized complete block design (RCBD) having three replications. Initially the soil was analyzed and mainly featured with loam textured, bulk densities 1.27 g/cc, particle densities 2.65 g/cc, pH 8.10 and organic matter 1.20%. After organic amendments the value in respect of bulk density, particle density and sand particles which were found to be decreased though porosity, moisture content and silt particles were increased. The chemical characters of soil like pH and carbon nitrogen ratio were noted as negative changes with probiotic and organic manures amendments. Furthermore, the organic matter content, total N, exchangeable K, available P, available S, available Zn and electrical conductivity were found to be improved during the three sequential years of the study. Seedling infection (14 days after sowing) and seedling blight (21 days after sowing) was examined and recorded significant reduction by the application of probiotic and organic manures. The probiotic fungi *T. harzianum* (T_5) significantly reduced the seedling infection and seedling blight by 86% and 81% in comparison with control treatment.

Total dry matter content increased with increasing the age of the crop. The leaf area index and crop growth rate was lower at the early stage of crop growth and reached a maximum during 55 and 55-70 days after sowing and then declined. All the aforesaid growth parameters were improved by the application of probiotic and organic manures application and produced maximum value especially with poultry manure combination (T_4) over control. Studied yield contributing characters including plant height, total plant/m^2, total tiller/plant, effective tiller/plant, awn length, spike length, spikelet/spike, fertile spikelet/spike, grains/spike, deformed grains/spike, grain weight/spike and 1000-grain weight were influenced significantly due to application of organic amendments. As grain yield positively linked with the above mentioned yield contributing characters, thus grain yield was significantly enhanced with organic amendments. Besides this, the straw yield and harvest index was also recorded upturned with the similar amendments. Grain yield, straw yield and harvest index showed 73%, 27% and 22% greater response at the final research period under poultry manure combination (T_4) over control. Seed quality parameters such as germination, vigor index and total soluble protein content significantly affected by different organic amendments. Among the treatments, poultry manure combination (T_4) exhibited higher results in this regard, whereas lower value was recorded in control. However, with few exceptions, V_3 (BARI Wheat-30) and T_4 (Poultry manure + vermicompost + green manure) not only individually performed better results than others but also their interactivity (V_3T_4) exhibited better results under this study.

In connection with the above findings, it can be recommended that the wheat growers to adopt the most efficient soil amendment option poultry manure + vermicompost + green manure (T_4) to improve soil fertility and productivity by its positive changing ability and to enhance the growth, yield and grain quality of wheat in a sustainable manner.

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

The following abbreviations have been used through the text:

AEZ	:	Agro-Ecological Zone
ANOVA	:	Analysis of variance
BARI	:	Bangladesh Agricultural Research Institute
BBS	:	Bangladesh Bureau of Statistics
BD	:	Bulk density
C:N	:	Carbon nitrogen ratio
CARE	:	Cooperative for American Relief Everywhere
CBB	:	Coomassie Brilliant Blue
CDM	:	Cattle dung manure
CGR	:	Crop growth rate
cm	:	Centimeter
cmol (+)/kg	:	Centimoles of positive charge per kilogram of soil
CRB	:	Crop residue burning
CRI	:	Crown root initiation
DAS	:	Days after sowing
DMRT	:	Duncan's Multiple Range Test
EC	:	Electrical conductivity
ECEC	:	Effective cataion exchange capacity
et al.	:	And others
FAO	:	Food and Agriculture Organization

FC	:	Field capacity
Fig.	:	Figure
FYM	:	Farmyard manure
FYMC	:	Composted farmyard manure
g	:	Gram
g/m^2	:	Gram per meter square
$g/m^2/d$	:	Gram per meter square per day
GDP	:	Gross domestic product
ha	:	Hectare
hr	:	Hour
i.e.	:	That is
IPNS	:	Integrated plant nutrient system
K	:	Potassium
Kg	:	Kilogram
Kharif	:	The wet season in Bangladesh (March to October)
LAI	:	Leaf area index
LS	:	Level of significance
LSD	:	Least significant difference
µg/g	:	Microgram per gram
m	:	Meter
m^2	:	Meter square
meq	:	Milliequivalent
Mg	:	Mega gram

Mg/g FW	:	Milligram per gram fresh weight
mm	:	Millimeter
MWHC	:	Maximum water holding capacity
N	:	Nitrogen
nm	:	Nanometer
NPK	:	Nitrogen, Phosphorus and Potassium
NS	:	Non-significant
OM	:	Organic matter
P	:	Phosphorus
PD	:	Particle density
PGS	:	Participatory guarantee system
P^H	:	Potentiality of hydrogen ion
ppm	:	Parts per million
Rabi	:	The dry season in Bangladesh (November to February)
RCBD	:	Randomized complete block design
S	:	Sulphur
SE	:	Standard error
SGM	:	*Sesbania* green manure
SOC	:	Soil organic carbon
SOM	:	Soil organic matter
SPAD	:	The soil plant analysis development
SRDI	:	Soil Resource Development Institute
t	:	Ton

TDM	:	Total dry matter
TMC	:	*Trichoderma* multiplied culture
UNDP	:	United Nations Development Programme
USDA	:	United States Department of Agriculture
viz.	:	Namely
WHC	:	Water holding capacity
Zn	:	Zinc
%	:	Percent
/	:	Per

Chapter I
Introduction

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) has long been a highly popular cereal crop all over the world, as it grows in many countries in the world. It is the third most widely produced agricultural commodity next to rice and maize, and it is a staple food of billions of people all over the globe. Bangladesh possesses 31st position among 80 wheat growing countries over the world, whereas the European Union possesses 1st position. Near about 50% total world grain crop production is occupied by wheat (Banglapedia 2014). Wheat occupies in Bangladesh 4% of the total cropped area and 11% of the cropped area in *Rabi* season and contributes 7% to the total output of food cereals (BBS 2008). In 2017, wheat occupies 415339 ha areas with yield 1311473 t which is 2.72% less compared over the year 2016 (BBS 2017). In Bangladesh, the average yield of wheat 3.16 t/ha (BBS 2017) which is below the achievable yield of 4.5 t/ha of wheat (BARI 2011). Alam et al. (2013) stated two reasons for the yield gap as (i) biotic factors including poor quality seeds and seedlings, insects, diseases, weeds and rodents; and (ii) abiotic factors including soil, nutrients and water. However, many reasons for this yield gap remain unexplained. Wheat is a global commodity which is being traded about 150 ton annually (World Agricultural Outlook Board 2014). It is a rich source of calories (327 kcal/100g) well as multiple nutrients such as protein, dietary fiber and minerals, manganese, phosphorus, niacin and several vitamins (Shewry et al. 2002). The contribution of wheat is being increased significantly in different countries as Nigeria (1%-6.64%), India (11.85-20.41%) and China (12.20-17.83%) regarding total kcal (Shewry and Hey 2015).

Bangladesh is known as a rapidly increasing populated country and thus land under cultivation is decreasing day by day to provide their accommodation. To keep harmony with increased population, intensive cultivation of land causes land degradation which affects food security. To face the land limitation problem and provide food for increased population sustainable use of land is burning issue for agricultural development (Alam et al. 2020). It is widely agreed that long-term application of excess inorganic fertilizer or poor fertilization practice may result in soil acidification and nutrient depletion as well as, health and environmental hazards (Liebig et al. 2002). For long-term application of unbalanced synthetic fertilizer, it is assumed that after a certain period of time the land will lose its fertility. Furthermore, synthetic fertilizers are chemicals in nature that are harmful to humans and animals. So, for achieving higher yield and to retain soil health sound, use of high yielding varieties along with organic amendments are felt to be important. The wheat-rice cropping system has emerged as the most productive cereal grain producing system in Bangladesh. This pattern is highly productive but very exhaustive. In Bangladesh, it has been observed that the nutrient balance for N is moderately negative, P is slightly negative and K is highly negative in soils (Rijpma and Jahiruddin 2004). The soil fertility, climatic conditions, characters of cultivar and yield considerably influence the nutrients requirements of the growing crops.

Soil organic matter is a positive factor for sustainable soil fertility and productivity. Organic matter undergoes mineralization with the release of substantial amounts of N, P, K, S and smaller amounts of micronutrients. Easily decomposable part of the soil organic matter undergoes mineralization quickly and becomes a part of soil humus, a small portion of which may remain in the soil. A good soil should have organic matter content of more than 2.5%. Most of the soils in Bangladesh have low to very low organic matter content, generally less than 1.5% (BARC 2012). The environmental conditions such as high temperature, high relative humidity and frequent tillage operation for high cropping intensity are favoring rapid decomposition that accelerates degradation of soil organic matter in Bangladesh (Ahsan and Karim 1986). Soil organic matter status strongly associated with soil productivity. Organic amendment improves the quality of soil, reduces compaction and crusting, and increases drainage and water-holding capacity. Plants become healthier, tolerant of drought, insects and diseases and more yields by providing organic matter. Soil organic matter serves as a reservoir for plant nutrients thus need less fertilizer (Cooperband 2002). Organic materials like crop residues, green manure, and animal manure and their spontaneous use shows great influence on soil productivity and N dynamics in the soil-plant system (Yadvinder-Singh et al. 2008). As a part of organic amendments of soil beneficial microbe populations are essential to creating the ideal soil environment for healthy plant growth. Probiotics like *Trichoderma* may be environmentally-friendly alternatives to the chemical fertilizers to increase the soil fertility and the crops productivity and yield without causing harmful environmental effects (Hajieghrari and Mohammadi 2016).

South Asian farmers need to manage 5-7 t/ha of rice residues and overcome the problems for planting wheat. Burning of rice straw before wheat planting results in huge losses of N (up to 80%), P (25%), K (21%) and S (4-60%), air pollution (CO_2 13 t/ha) and soils depriving organic matter (SOM). This loss of SOM is one of the recognized threats to sustainability (Mandal et al. 2004). Residue management practices affect soil physical properties *viz.* soil moisture, temperature, aggregate formation and bulk density. Rice crop residues reduce P fixation; improving base retention and increasing the soil pH. Rice straw incorporation coupled with organic manure increases grain yield of wheat as well as improves soil physical condition. The soils having crop residue enhances the microbial activities than residue removal or burning. Besides the rice straw, grain legumes mung bean also offers considerable increased value in production when its plant residue is incorporated into soil. Incorporation of N-fixing legume crop residues into the soil may provide organic N for the subsequent benefit of a cereal crop (Rosales et al. 1998). The use of mung bean residues in the rice-wheat cropping system was equivalent to the use of 30-120 kg urea-N/ha (Sharma et al. 2000). However, crop residue might also affect other factors, such as the soil pH and soil organic content and also soil structure and plant growth (Ghassan et al. 2017). Thus, if residues are managed properly, then it can warrant the improvements in soil properties and the sustainability in crop productivity. The most economical and ecological means of conserving soil and water and sustaining crop production is returning crop residues to soil (Wilhelm et al. 2007).

In Bangladesh, cow dung is generally used for crop production, but small mechanization in the crop production field resulted in lessen use of livestock as well as cow dung. Then again, generally rural farmers are using cow dung as fuel for cooking purposes. Cow manure is packed with high levels of minerals and nutrients and is one of the best natural fertilizers to use in organic farming. Cow dung contains an average of 1.04% nitrogen, 0.15% potassium and 0.78% phosphorus and 32 other micronutrients. Manure applications result in increases in pH, water holding capacity and infiltration rates (Ram 2017). Soil conditioning ability of cow manure is outstanding which is not comparable to fertilizer.

Land is the major non-renewable resource and faces the biggest threat of degradation. Nutrients availability of soils is declining with time pace but which have been rich in the past (Zia et al. 1994). Use of compost can be beneficial to improve organic matter status of soil. Compost is a prosperous source of nutrients with high organic matter content. Physical and chemical properties of soil can be improved by using compost, which may ultimately increase crop yields (Sarwar et al. 2008). Besides soil health improvement, compost leads to managing large volumes of organic wastes in a comprehensive manner (Lasaridi and Stentiford 1999).

Vermicomposting is an effective means of composting the decomposable organic wastes using earthworms naturally present in the soil. Vermicompost is an excellent vehicle for carrying nutrients to soil and plants as it is more than a fertilizer (Sheela and Khimiya 2013). Vermicompost is a mixture of worm casts enriched with macro and micronutrients (N, P, K, Mn, Fe, Mo, B, Cu and Zn), some growth regulating substances (gibberellins and auxins) and useful to micro flora which naturally helps in improvement of soil fertility or soil quality (Dandotiya and Agrawal 2014). Vermicompost is associated with the improvement of soil physical properties like aggregate formation, bulk density and porosity having its excellent structure, porosity, aeration, drainage and moisture holding capacity (Dominguez et al. 1997). In fact, there must be a balance between soil degradation and restoration process to determine sustainability. To maintain these phenomena vermicompost may be a viable tool for soil amendment and signifies quality produce of crops.

Green manure is a once grown crop and usually incorporated to the soil before the next cash crop. It is grown for a short time and dug into soil so that organic matter in the crop can be transferred back into the soil. In Bangladesh, the aus rice is cultivated from March and April after the pre-monsoon rainfall and harvested between July and August (Shelley et al. 2016).

Thus after harvest of rice and cultivation of wheat there is a short fallow period of 40-70 days. This fallow period of about 2 months between rice harvest and wheat cultivation can be used effectively for raising a suitable legume crop. In this system crop productivity and maintaining soil fertility can be definitely improved by adding green manures. It has been noticed by researchers that green manures increase soil biological and enzymatic activities more than mineral fertilizers (Bolton et al. 1985, Kirchner et al. 1993, Abdallahi and N'Dayegamiye 2000). Green manures also showed remarkable improvement in soil structural stability and higher water-holding capacities (Muller et al. 1988, Kuo et al. 1997, Abdallahi and N'Dayegamiye 2000) and resulting in higher crop yields and nutrients availability.

Recently, the poultry industry possesses a remarkable stand and creates an opportunity to utilize poultry manure in organic farming in Bangladesh. Poultry manure is available fertilizer and can serve as a suitable alternative to chemical fertilizer. Over 53% increase of N level in the soil from 0.09 to 0.14% and exchangeable cations increase was noticed with manure application (Boateng et al. 2006). Mainly poultry manure provided to soil in order to include the organic amendment of the soil and the provision of nutrients to crops (Warren et al. 2006). As poultry manure contains high N, P, K and other essential nutrients thus it is an excellent organic fertilizer (Farhad et al. 2009). Poultry manure has been reported to supply P ready to plant than other organic sources (Garg and Bahla 2008). It shows more significant compared to farmyard manure and vermicompost (Behara and Pandey 2002) and its application was near about 1.5 times more effective than compost (Singh et al. 1983). Li et al. (2011) explained that poultry and livestock manure influence pore structure and aggregate stability where pore structure plays a very important role in soil structure formation, soil moisture and maintaining nutrients, and protection of microbial diversity, while aggregate stability has a positive impact on the seed germination, plant roots and shoots development. So poultry litter is a valuable, natural soil amendment that adds nutrients and organic matter to increase soil fertility.

Probiotics are live microorganisms which confer a beneficial health benefit on the host. *Trichoderma* are model organisms to demonstrate influence on plant health as applied bio-fertilizer (Berg 2009). *Trichoderma* is considered as a probiotic having the characteristic of fungi and considered as a potential and promising bio-control agent and growth promoter for many crops. Bio-fertilizer is regarded as an eco-friendly substitute of chemical fertilizer trends to enhance soil fertility and increase crop productivity and yield without creating harm to the environment (Mihov and Tringovska 2010, Hermosa et al. 2012). *Trichoderma* has been a common component of bio-fertilizer which is a common inhabitant in soil and common symbiont of plant root (Sharma et al. 2012, Vinale et al. 2012). *T. harzianum* can solubilize several plant nutrients (Altomare et al. 1999) and *T. asperellum* has been shown to enhance the availability of P and Fe to plants, with significant increases in dry weight, shoot length and leaf area (Yedidia et al. 2001). Application of *Trichoderma* as a stand-alone agent, or in combination with compost or manure can significantly boost yields in rice and vegetables. Nahar et al. (2012) stated that soil applications of tricho-compost and tricho-leachate significantly increased the seedling germination rate and reduced the incidence of soil-borne diseases and infestation of root-knot nematodes and also reduced the seedling mortalities by 40.9% to 64.5% in Gazipur and 53.3% to 62.1% in Bogra, Bangladesh. It was established that *Trichoderma* is a biological degrader and promotes plant disease defense, increasing the immunity of the plant. Hence, *Trichoderma* have tremendous opportunities for disease management of soil borne pathogens but also have the capacity to improve plant growth parameters, and soil health.

Among different agricultural inputs fertilizer is the most important one and nearly 50% of the modern agricultural production depends on this insert (Pradhan 1992). It is authentic that fairly good soil fertility and plant nutrients are important to farming, whether the practices are considered “conventional” or “sustainable” (Hue and Silva 2000). But in agriculture conventional practices like excess tilling, injudicious application of readily soluble inorganic fertilizers and pesticides formulations have potentially damaged the environment.

To minimize environmental damages and promote economic feasibility agricultural producers have shown interest switching from “conventional” to “sustainable” agriculture. Although sustainable farming is often a much broader concept than “organic” farming, sustainable farming also emphasizes use of organic materials as soil amendments and sources of plant nutrients. Hence to improve soil fertility and increase plant nutrients availability, efforts need to be made to increase soil organic matter content. Therefore, the present research work has been carried out on the following objectives:

i. To study the effect of soil amendments on physical and chemical properties of soil.

ii. To analyze the impact of soil amendments for better crop growth environment.

iii. To determine the effect of soil amendments on growth and development of wheat plants.

iv. To determine the effect of soil amendments on yield, yield attributes and grain quality of wheat.

Chapter II

Review of Literature

2. REVIEW OF LITERATURE

Producing more crops per unit area is the present need of Bangladesh in order to obtain maximum return from the total cultivable land as well as to meet up the demand of food for the increasing population. Due to unrest cultivation of land, it loses its natural inheritances which affects crop yield. Soil fertility is a measure of the ability of soil to sustain satisfactory crop growth in the long-term, and can be determined by physical, chemical and biological processes intrinsically linked to soil organic matter content and quality. Effective management of organic matter in the field should conserve soil with minimal adverse effects on the environment. The information generated from different research works by many investigators on various aspects of soil amendments have been reviewed in this chapter.

2.1 Fertility situation of soil in Bangladesh

Though Bangladesh is a small country, it has a wide variety of soils. The status of fertility in Bangladesh soils is extremely variable. Most of the soils are depleted and in urgent need of replenishment with manure and fertilizer if productivity is to be enhanced. Nutrient supply ability of soil is known as fertility. It is a combined activity of physical, chemical and biological composition of the soil environment. In Bangladesh, the fertility of soil is deteriorating day by day (BARC 2005).

Vast population of Bangladesh pressured the land resources to derive necessary food, fiber and fuel over the last 2-3 decades. Expansions of modern crop varieties increase the land use intensification. This creates noticeable injury to the land qualities for non judicious withdrawal of plant nutrients by growing crops without proper replenishment. Land degradation occurs when land qualities are affected negatively due to natural causes or human interference. This is very much true for Bangladesh. Thus, plant nutrient deficiency/unbalance, soil organic matter depletion, soil erosion, soil compaction, flash flood, water logging etc., have emerged as vital problems as the result of irrational land use (Karim and Iqbal 2001).

2.1.1 Status of organic matter

Organic matter is called the ‘storehouse of plant nutrients’ and ‘life force of the soil’. Organic matter plays a great role in successful crop production as well as soil fertility and crop productivity. In Bangladesh, mostly agricultural soils content low organic matter. A good soil should have at least 2.5% organic matter, but in Bangladesh most of the soils have less than 1.5%, and some soils even less than 1% organic matter (BARC 2005). Islam et al. (1994) found that organic matter ranged from 0.6 to 1.7% in 29 soil series from different regions of the country. Islam (1990) reported that at least 2% organic matter should be present in the soil for successful crop production. But, he observed that 90% soils of Bangladesh contained 0.5-1.0% organic matter. On the other hand, Akter (2011) reported that organic matter content in soils of eight, out of ten soil series namely Silmondi, Tejgaon, Chandra, Khilgaon, Halma, Brahmapra, Jamalpur and Sherpur gradually increased since 1991 having the values of 0.57-3.02% in 1991, 0.9-2.29% in 2006 and 0.91-3.02% in 2011.

In Bangladesh, it is true that high cropping intensity causes depletion of soil organic matter which declines the productivity of soils. Lack of organic recycling through addition of crop residues, animal waste, and other organic manures are the main reasons of low organic matter content in Bangladesh soils. Mia and Karim (1995) mentioned that 81% of the total biomass fuel is consumed for domestic cooking. FAO and UNDP (1994) reported that decreased organic matter leads to the degradation of soil physical properties including water holding capacity and reduced nutrient retention capacity leading to the lower release of nutrients from mineralization of organic matter. Over the 20 years, due to intensive cultivation, average organic matter content of the top soil has decreased by 20-46% presented in Table 1 (Appendix).

A pilot survey in Jessore and Kushtia revealed that 73% of the farmers faced yield decline leading to reduced soil fertility due to the cultivation of continuous cereals or increased cropping pressure (Saunders 1991). Eighty-eight percent of wheat growing farmers applied farmyard manure (FYM), of which 30% applied pure cow dung, and most farmers who applied FYM did so each year, mostly after wheat harvest. In 1998, CARE (Cooperative for American Relief Everywhere) interviewed the farmers of different regions of

Bangladesh and recorded their expressions about organic matter. They said that soils become more hard and compact, losing structure and water holding capacity for intensive inorganic fertilizer use. Farmers said that inclusion of organic matter increased yield, reduced production cost, improves crop growth, increased water holding capacity and improves soil structure. They also reported that farmers realized the addition of cow dung and other organic manure as also leaving crop residues increased the organic matter content of the soils.

There is no separate policy for supporting organic farming in Bangladesh. The national food policy of 2006 is the main document on food security in Bangladesh. Recently, the cabinet approved the food safety act, 2013 to save the people from adulterated and contaminated food. During recent days, Bangladesh Agricultural Research Institute (BARI) initiated the Participatory Guarantee System (PGS) for authentications. It will add more value to the consumer and organic promotion as well. PROSHIKA and Unnyan Dhara created organic consumer groups and sold their products directly to the farmers (Musa et al. 2015).

2.1.2 Selected essential nutrient status

Our life and food security is closely related with proper soil management. So, it is an urgent issue to identify the main constraints related to physical, chemical and biological nature and integrating them for improvement in effectiveness of input use, crop yield and quality, soil fertility and overall sustainability. In Bangladesh, soil fertility deterioration is a main constraint for higher crop production. Use of low external sources of nutrients and continuous cropping are also defined as the constraints to restore the soil nutrients. Thus depletion of soil fertility is mainly due to exploitation of land without proper replenishment of plant nutrients.

Ali et al. (1997) reported that on an average, the total carbon content has decreased by 11%, the total N by 12%, pH decreased by 4% and the exchangeable acidity increased by 30%. The exchangeable K content in soil has decreased by 31% and available P showed a decline of about 9% over a period of 27 years (1967-1995) in Bangladesh.

As the time advances, new nutrient deficiency arises in soil. Six mineral elements such as N, P, K, S, Zn and B are commonly deficient in Bangladesh soils. In the early 1980s, S and Zn deficiencies in rice were observed. But another study by Ali et al. (2012) presented, change in organic carbon and total N contents showed an increase in most of the layers in different soils of Ganges River Floodplain during the period between 1960s and 2010. Magnesium is reported to be deficient in Old Himalayan Piedmont Plain and Tista Floodplain soils (OFRD 1998). The chronological deficiencies of nutrients with time are shown in Table 2 (Appendix).

2.2 Organic amendments and soil properties

2.2.1 Non-leguminous crop residue incorporation and soil properties

Cassman et al. (1998) mentioned that crop residues are a potential source of organic matter and it needs efficient management. If crop residues are managed efficiently, it can increase organic matter as well as soil N. Addition of organic matter in soil can improve soil health, meets the demand for N. Since one-third of total rice plant N is in the straw, the N fertilizer requirements may be replaced partially by returning straw to the field. Munawar et al. (1990) mentioned that crop residues placed on the soil surface reduce water loss by evaporation due to their mulching effect. Walters et al. (1992) and Nyborg et al. (1995) mentioned, respectively that a crop residue is a vital source of conserving and sustaining soil productivity. It is the primary substrate for replenishment of soil organic matter (SOM). Upon mineralization, crop residues supply essential plant nutrients. Additionally, improvement of the soil physical and biological conditions and prevents soil degradation by residue incorporation.

Patra et al. (1992), Sidhu et al. (1995) and Samra et al. (2003) reported that regular addition of sufficient amounts of organic materials, such as crop residues to the soil leads to the maintenance of microbial biomass and improvement of soil fertility. Liu and Shen (1992) and Meelu (1994) mentioned that removal or burning of crop residues deteriorated soil physical properties, while incorporation of crop residues into the soil under rice-based cropping systems improved soil aggregation. Crop residues also play an important role in maintaining soil physical conditions (Prasad and Power 1991).

Beri et al. (1995) conducted field experiments in India on the rice-wheat cropping system that resulted in both nutrient contents and their availability increased with the incorporation of crop residues compared with their removal or burning. In an 11 year field experiment on a loamy sand soil in the Punjab, the incorporation of residues of both crops in the rice-wheat cropping system increased the total P, available P and K contents in the soil over the removal of residues. In another study over a 5 year period on a silt loam soil in Himachal Pradesh, the incorporation of rice straw in wheat caused a slight increase in the availability of P, Mn and Zn and a marked increase in the availability of K (Verma and Bhagat 1992). Sen and Jana (1998) undertook a field trial and opined that 65-70% of the total moisture was extracted by rice from the upper 30 cm soil layer. Incorporation of organic residues in soil holds water fairly tightly, increasing water holding capacity, soil porosity and helps the root respiration. Kumar and Goh (2000) stated that crop residues are an important source of organic matter that can be returned to soil for nutrient recycling, and to improve soil physical, chemical and biological properties.

Basic et al. (2004) and Lal (2005) showed the positive side, retaining residues on the surface through conservation tillage is important in reducing P losses, as this practice alleviates runoff and erosion losses. Zeleka et al. (2004) found a significant decrease in bulk density, an increase in macro plus meso-porosity, and a decrease in penetration and shear resistance in systems where maize residues were incorporated annually over 3 years than where residues were removed. Kharub et al. (2004) observed in a field experiment and reported that N and K uptake by crop was higher when rice straw was incorporated in the field alone and was highest when incorporated along with green manure.

Bonde et al. (2004) observed that all the organic residues significantly lowered the bulk density over the control. Among different organic residues, FYM recorded greater value of availability of nitrogen, phosphorus and potassium in soil as compared to other treatments (wheat straw and press mud compost treatments) including control, in the cotton-soybean cropping system. Mandal et al. (2004) determined that despite some advantages like killing of deleterious pests and clearing the piles before wheat planting, burning results huge losses of N (up to 80%), P (25%), K (21%) and S (4-60%), air pollution (CO_2 13 t/ha) depriving soils of organic matter (SOM). This loss of SOM is one of the recognized threats to sustainability. Soil physical properties *viz*. soil moisture, temperature, aggregate formation, bulk density and hydraulic conductivity affected by residue management practice. High siliceous content of rice crop residues have the potential of transforming electrochemical properties of acidic soils that reduces P fixation, improving base retention and increasing the soil pH.

Lal (2005) mentioned that globally the total crop residue production is estimated at 3.8 billion tons per year, of which 74% are from cereals, 8% from legumes, 3% from oil crops, 5% from tubers and 10% from sugar crops. Besides C, crop residues contain all mineral nutrients, the content of which varies among crop species depending on the fertility of the soil. Saddiq and Al-Amir (2011) conducted a study in fall 2009 at the College of Agriculture, Babylon University to determine effects of two types of organic matter on the physical properties of clay soil. The results showed a significant increase in both soil saturated hydraulic conductivity and soil porosity with the addition of chicken waste and rice straw. The increases were more pronounced with chicken waste than with rice straw and the values of the bulk density decreased significantly with organic matter addition to the soil. Dhar et al. (2014) observed the lowest soil pH (7.70) with soil incorporation of wheat straw and green manure in alluvial soil due to the production of organic acids during decomposition. Electrical conductivity of the soils was not significantly influenced by the incorporation of organics. Shahrzad et al. (2014) reported an increase in pH and electrical conductivity of soil with incorporation of crop residues. Chaudhary et al. (2017) conducted a long-term fertilizer experiment in rice-wheat cropping system at Punjab Agricultural University, Punjab on sandy loam soil revealed that the incorporation of straw + NPK increased total soil porosity (46.3%) and decreased the bulk density (1.42 Mg/m^3) up to 0-15 cm when compared to 100% NPK treated plots (43.1%, 1.51 mg/m^3, respectively).

2.2.2 Leguminous residue incorporation and soil properties

Sharma et al. (2000) studied the effect of *Sesbania aculeata* green manure and mung bean (*Phaseolus radiatus* L.) residue incorporation on rice-wheat cropping system. They reported the soil chemical properties showed that *Sesbania* green manure and mung bean residue incorporation increased soil organic C over summer fallow by 0.105-0.135%, Kjeldahl N by 0.01% and available P by 5.0-5.5 kg/ha and positive effect was observed in the *Sesbania* green manure and mung bean residue incorporated plots but not in summer fallow plots. Additionally, they concluded through incorporation practice of *Sesbania* green manure and mung bean residue interact positively in building-up of soil N. Sharma and Prasad (2008) stated that the return of rice and wheat residue can recycle up to 20-30% N absorbed by the crop. Native and applied N can temporarily immobilize for their wide C:N ratio. They opined that combining application of wheat straw with *Sesbania* green manure or mung bean residue increased cereal grain yield and agronomic N efficiency and generally improved negative apparent N balances.

Sing et al. (2008) carried out an experiment having sorghum and mung bean-lentil cropping system, for three successive years to assess the effect of mung bean residue incorporation on sorghum and succeeding lentil productivity along with different doses of phosphorus (0, 30 and 60 kg/ha) applied to these crops. When 60 kg P_2O_5/ha was applied and mung bean residue incorporated then the result showed that sorghum grain yield increased significantly and available soil nitrogen, phosphorus, and organic carbon content were increased with incorporation of mung bean residue. Naeem et al. (2009) evaluated the efficacy of organic and inorganic fertilizers and mung bean residue under wheat-mung bean-wheat cropping system where mung bean was grown with basal dose of 25-60 kg N-P_2O_5/ha was applied. After mung bean harvest, three residues management practice, i.e. R + (mung bean residue incorporated into soil), R- (mung bean residue removed) and F (fallow) were performed in the main plots. The result obtained microbial biomass C, N, mineralizable C and N from R+ compared with fallow increased by 33.7, 47.4, 21.4 and 32.2% at surface and 36.8, 51, 21.9 and 35.4% at sub-surface soil, respectively.

Singh et al. (2011) carried out a research in a mung bean/urd bean-wheat cropping system to assess the effect of different methods of legume residues management along with N fertilizer on succeeding wheat yield and soil properties. They analyzed collected data and reported significant improvement in the number of panicles/unit area with different residue management (10.2-20.9%) over residue removal. Moreover, residues incorporation presented higher soil available major nutrients *viz.* N by 24.6%, P by 11.5% and K by 18.5% over initial levels and bulk density, particle density, percent pore space and water holding capacity (WHC) like soil physical properties were also improved in residues incorporated plots over residues removal plots. Buarach et al. (2014) conducted a study to determine the effect of tillage systems and soil organic amendments on rice growth, yield and carbon sequestration on paddy soil including two factors: the first factor was included conventional tillage; t_o and minimum tillage; t_1 (tillage systems) and the second factor was included mung bean; p_0, S*esbania*; p_1, sunhemp; p_2 and rice straw; p_3 (soil organic amendments). The results demonstrated that tillage systems with a mung bean amendment tend to increase the rice yield as also soil organic matter was the highest in sunhemp amendment in soil as followed by S*esbania*, mung bean and rice straw, respectively.

Ghassan et al. (2017) conducted a pot trial to analyze the influence of mung bean residue on the properties of soil involving three levels of mung bean residue at three incubation periods (5% + 1 week, 5% + 2 weeks, 5% + 4 weeks, 10% + 1 week, 10% + 2 weeks, 10% + 4 weeks, 15% + 1 week, 15% + 2 weeks and 15% + 4 weeks) and control treatment. The results showed that the values of calcium, potassium, magnesium, CEC, phosphorous, organic carbon, organic matter and carbon: nitrogen ratio were significantly ($p < 0.05$) higher than that of the control treatment and they concluded that mung bean residue is effective in increasing the fertility of the soil.

Farooq et al. (2018) examined the integrated effect of allelopathic residues and NPK fertilizer treatments including T_0 (control), T_1 (200-150-100 kg NPK/ha), T_2 (100-75-50 kg NPK/ha + mung bean straw 4 t/ha), T_3 (100-75-50 kg NPK/ha + rice straw 4 t/ha), T_4 (mung bean straw 8 t/ha) and T_5 (rice straw 8 t/ha) in wheat production under different water regimes on soil fertility. The result revealed that among fertilizer treatments, mung bean residue caused a greater increase in soil organic carbon, available nitrogen and available phosphorus, while there was a maximum percent increase in available potassium with T_1 (200-150-100 kg NPK/ha). But maximum wheat grain yield (30% and 33%) was obtained from the treatment T_2 (100-75-50 kg NPK/ha + mung bean straw 4 t/ha) during 2014-2015 and 2015-2016, respectively.

2.2.3 Cow dung incorporation and soil properties

Rahman (2001) reported that the inclusion of green manure in the cropping pattern and addition of cow dung resulted in a slight decrease in pH. There was a little increase in available P, K, S and Zn contents in soil after three crop cycles. Matsi et al. (2003) investigated the influence of liquid cattle manure on winter wheat (*Triticum aestivum* L.) germination, growth, and nutrient utilization by applying four treatments in the same plots in a 4 years field experiment with winter wheat: (i) application of 40 Mg/ha/yr liquid dairy cattle manure (wet weight basis) before sowing; (ii) single application of 120 and 26 kg/ha/yr N and P, respectively, as inorganic fertilizers before sowing; (iii) as in ii, but with split application of N, half the amount before sowing and the rest at tillering; and (iv) no fertilization. The results showed that application of manure did not affect seed germination, but resulted in a significant increase in dry biomass at the two growth stages and in grain yield and nutrient uptake, similar to the inorganic N and P fertilization.

Adeniyan et al. (2011) conducted a pot experiment to compare different organic manures with NPK fertilizer and results showed that application of 5 t/ha of each of the evaluated organic manures and 100 kg/ha NPK 15:15:15 fertilizer improved chemical properties of both acid and nutrient depleted soils compared with unfertilized soil. Cow dung application resulted in the highest pH levels of 6.37 and 6.50 in acid soil and nutrient depleted soil, respectively, while NPK fertilizer gave lowest pH levels of 5.28 and 5.74 for both soils. Moreover, application of different types of organic manures enhanced soil organic C, total N, available P, exchangeable K and CEC better than NPK fertilizer in both soils. Santillan et al. (2014) studied the effect of cow manure application on soil chemical properties and concluded that the sites with manure application, organic matter content increased significantly compared to the control plot (1.24 and 1.43%), the addition of manure for several years contributed to lower soil pH value.

Ram (2017) stated that the most important significance of cow dung and cow manure is to maintain the organic microbial and mineral micronutrient richness of soil and as a medicine for plants. Report made on cattle manure contains an average of 1.04 percent nitrogen, 0.15 percent potassium, 0.78 percent phosphorus and 32 other micronutrients having the characteristics of low nitrogen release and spread over time.

They further stated that manure applications result in increases in pH, water holding capacity, hydraulic conductivity, infiltration rates and soil amending properties of this great natural fertilizer are unbelievable.

2.2.4 Compost incorporation and soil properties

Prasad and Kerketta (1991) conducted an experiment to assess the soil fertility, crop production and nutrient removal under different cropping sequences in the presence of recommended doses of fertilizer and cultural practices along with 5 t/ha compost applied to the crops. There was an overall increase in organic C, an increase in total N (83.9%), available P (117.3%) and CEC (37.7%). Compost application also decreases soil bulk density (Park et al. 1995). Ouedraogo et al. (2001) assessed the impact of compost on improvement of crop production and soil properties where compost were applied at the rate of 0 and 10 Mg/ha and 5 and 0 Mg/ha. They found no significant difference in soil organic matter content between treatments receiving compost and no-compost. However, compost application increased soil cation exchange capacity (CEC) range 4 to 6 cmol (+)/kg and soil pH was also increased by the compost application. Sorghum yield tripled on the 10 Mg/ha compost plots and increased by 45% on the 5 Mg/ha compost plots, compared to no-compost plots.

Eghball et al. (2004) conducted a study to determine the residual effects of annual or biennial application of N and P-based compost and manure on corn. Results showed that residual effects of N and P-based compost and manure application on corn grain yield and N uptake remain at least one growing season, whereas the effects on soil properties were lasting longer. The residual effects of compost and manure increased significantly soil pH, electrical conductivity and plant available P and NO_3-N concentration. Gil et al. (2007) described an alternative approach for cattle manure management on intensive livestock farms in industrial-scale composting plants. The resulting compost was applied to a field to study the viability of applying this compost combined with a nitrogen mineral fertilizer as a replacement for the mineral fertilization conventionally used for maize (*Zea mays* L.). One year later, soil pH, OM content and CEC were higher with the compost treatment. Total P, K, Ca and Na concentrations in compost-amended plots were higher than in mineral-fertilized ones.

Tejada et al. (2009) carried out an experiment and mentioned that among the advantages of compost as soil amendment is its potential to maintain soil organic matter, foster nutrient availability and increase soil microbial population and activity, thus enhancing soil quality and fertility. Vengadaramana and Jashothan (2012) obtained soil from 10 different areas in Jaffna peninsula and evaluated the effect of organic fertilizers such as compost fertilizer and cow dung on the water holding capacity (WHC) of those soils. A significant difference ($p \leq 0.05$) was observed on mean WHC of each soil sample with compost fertilizer and cow dung treated separately when compared to the control. Addition of compost fertilizer and cow dung separately increased the mean WHC of each soil sample. Cow dung doubly increased the WHC of each soil sample.

Desta (2015) evaluated the effects of organic and inorganic fertilizers on soil fertility for two consecutive years using maize under rain fed conditions. Experimental treatments included factorial combinations of three rates of N (0, 60 and 120 kg/ha), compost (0, 5 and 10 t/ha) and S (0, 15 and 30 kg/ha) fertilizers which were laid out in RCBD with three replications. In comparison to the initial soil, results showed that integrated application of organic and inorganic fertilizers improved soil total porosity, pH, OC, total N, CEC, available P and S by 31.8, 0.9, 58.1, 20.0, 3.1, 29.8 and 38.9%, respectively but decreased bulk density by 26.1% in 0-30 cm soil depth. The plots were treated with compost applied 10 t/ha and S 30 kg/ha had revealed the lowest bulk density and the highest total porosity, while combined application of N 120 kg/ha, compost 10 t/ha and S 30 kg/ha showed the highest total N, available P and S. The highest OC and CEC were recorded in plots treated with N 60 kg/ha along with compost 10 t/ha.

Zaki (2016) conducted an experiment and reported that after addition of compost to soil at two rates (5 and 10 t/fed) in combination with three rates of N fertilization (35, 50 and 70 kg N/fed). The obtained data indicated that increasing N fertilization from 35 to 70 kg N/ fed increased significantly straw, grain and 1000-grain weight of rice as well as the high yield values of straw 2.88 t/fed, grain 2.11 t/fed and 1000-grain weight 35.50 g was obtained under a high level of the N fertilization and compost rate (70 kg N/fed and 10 t/ fed, respectively).

2.2.5 Vermicompost incorporation and soil properties

Gaind and Nain (2007) investigated to evaluate the relative contribution of organic fertilizers (paddy straw, microbial inoculants and vermicompost) and inorganic fertilizers (urea and superphosphate) in improving pH, C, N, humus, microbial biomass, dehydrogenase, phosphatase, cellulase, b-glucosidase and xylanase activities of soil under wheat crop. In wheat, soil vermicompost fertilization resulted in the highest microbial biomass, available phosphorus, and nitrogen content. Its effectiveness in minimizing the alkalinity of soil was also recorded compared to other treatments as indicated by pH change.

Ramesh et al. (2009) studied the combination effect of different organic manures on the productivity of crops and soil quality in India. Four cropping systems involving soybean (*Glycine max* L.), durum wheat (*Triticum durum* Desf.), mustard (*Brassica juncea* L.), chickpea (*Cicer arietinum* L.) and isabgol (*Plantago ovata* Forsk) were tested with the cattle dung manure (CDM), poultry manure (PM), and vermicompost (VC) vis-à-vis mineral fertilizers. The organic manures were applied based on the N-equivalent basis and nutrient requirement of individual crops. At the end of the 3-year cropping cycle, application of organic manures improved the soil-quality parameters *viz.* soil organic carbon (SOC), soil available nutrients (N, P and K) and soil bulk density. The highest SOC and accumulated higher soil available N, P and K recorded from the cropping systems, soybean-durum wheat. Where the manures applied in different combinations improved the soil quality and produced the grain yields which are at par with mineral fertilizers.

Tharmaraj et al. (2011) carried out an experiment to study the impact of various worm products such as vemicompost, vermiwash and mixture of vermicompost and vermiwash on soil physico-chemical properties during the pot culture studies of samba rice. They collected soil sampling and plant growth measurements for two months, i.e. during initial and final stages. Distinct enhancement were found in vermicompost treated soil involving physical properties such as the pH, electrical conductivity (EC), porosity, moisture content, water holding capacity and chemical properties like nitrogen, phosphorous, potassium, calcium and magnesium, whereas the corresponding physical and chemical values in control were minimum. The physical properties were improved in vermicompost treated soil such as water holding capacity, moisture content and porosity. The addition of vermicompost resulted in a decrease of soil pH.

Choudhary and Kumar (2013) stated that replenishing nutrients through organic sources is essential to maintain the soil health and sustainability in Eastern Himalayan Region, India which is organic by default. Keeping this in mind an experiment was laid out on randomized block design with six treatments *viz.* T_1: Vermicompost (VC; 2.5 Mg/ha), T_2: Poultry manure (PM; 1.25 Mg/ha), T_3: Swine manure (SM; 3.0 Mg/ha), T_4: Cow dung manure (CDM; 10.0 Mg/ha), T_5: Farmyard manure (FYM; 10.0 Mg/ha) and T_6: Control, and replicated three times to study the effect of applied organic nutrients on growth and yield of maize. When the crop was supplied with FYM followed by CDM physical indication like porosity, maximum water holding capacity (MWHC), field capacity (FC), bulk density (BD) and moisture releasing pattern was measured better. Chemical parameters like pH, Soil organic carbon (SOC), available nitrogen (N), phosphorus (P) and potassium (K) were recorded better on VC followed by PM over control.

2.2.6 Poultry manure incorporation and soil properties

Das et al. (1992) observed that application of poultry manure at the rate of 5 t/ha increased the uptake of Ca, Mg, K, Fe and also soil organic carbon. Obi and Ebo (1995) also reported that application of organic sources, i.e. poultry manure significantly increased soil organic matter content, total porosity, infiltration rate and hydraulic conductivity. Khanam et al. (2001) observed that the continuous use of chemical fertilizers accelerate the depletion of soil organic matter and impairs physical and chemical properties of soil in addition to micronutrient deficiencies. Poultry manure contains a high amount of secondary and micronutrients in addition to N, P and K. When poultry manures are applied to the field, it may supply sufficient amounts of S, Zn and B to meet up the demand for the growth of rice plants.

Agbede et al. (2008) conducted an experiment using the same plots in three years to determine the effect of poultry manure to sorghum at the rate of 7.5 t/ha. The poultry manure significantly ($p > 0.05$) reduced soil bulk density and temperature but increased porosity and moisture content. The poultry manure increased significantly soil organic matter, soil and leaf N, P, K, Ca and Mg concentrations. Furthermore, plant height, leaf area and weight of roots, shoot and grain yield were significantly increased. The mean grain yield was increased by 39%. The poultry manure had a cumulative effect on soil properties, growth and yield parameters over the three years of study.

Ru et al. (2012) worked on the effect of different chicken manure rates on crop yields and the soil nutrients accumulation were carried out by a field plot experiment aimed at resolving the unreasonable disposition and disadvantage to the environment from poultry manures. The results showed that appropriate application rate of chicken manure significantly increased the yield of wheat. The soil organic matter, total nitrogen (N), total phosphorus (P), total Zinc (Zn) and nitrate (NO_3^-), available P and available Zn contents significantly increased with the increasing rates of the chicken manure.

2.2.7 Green manure incorporation and soil properties

Mandal et al. (2003) conducted a field experiment on rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) with objectives to study the influence of different green manure (*Sesbania rostrata*, *Sesbania aculeata*, *Vigna radiata*) residues and in combination with different levels of nitrogen (0, 60, and 120 kg N/ha) on physical properties, organic matter and total nitrogen contents of soil. They found that organic matter and total soil nitrogen concentrations was higher under green manure treated plots than summer fallow and magnitude of reduction in bulk density due to green manure over fallow was 0.03-0.07 t/m^3 in 0-15 cm soil layer and 0.05-0.09 t/m^3 in 15-30 cm soil layer during the growth of rice and wheat. Green manure also improved the soil physical environments and saturated hydraulic conductivity than fallow.

Sultani et al. (2007) studied physical properties of soil influenced by various green manure legumes (*Sesbania*, cluster bean and rice bean) and different P levels (0, 30, 60, 90 kg P_2O_5/ha). They noticed that highest fresh biomass was observed in *Sesbania* (23 t/ha) followed by cluster bean (19 t/ha) and lowest in rice bean (17 t/ha) as also green manure crops, on average reduced soil bulk density (5%) enhanced total porosity (8%), and macro pores and large meso pores (28%). An increase (11%) in total soil porosity and available water (17%) was observed in plots and decrease (7%) in soil bulk density where *Sesbania* was incorporated as a green manure crop. The application of chemical phosphorus showed meager positive impact on various soil physical properties but did not significantly increase porosity or reduced bulk density.

Deshpande and Devasenapathy (2010) studied the effect of green manure and different sources of organic manures on yield and soil chemical properties of rice. They reported green manure incorporation along with poultry manure application resulted in higher soil available N, P and increased K uptake and higher N and P uptake and increased soil available K was recorded with green manure and poultry manure application. In another context, incorporation of green manure in situ, vermicompost and poultry manure decreased the soil pH and increased the organic carbon content of soil compared to all other combinations of treatments. Jat et al. (2012) conducted a field experiment at New Delhi during the *Kharif* and *Rabi* season of 2006-2007 and 2007-2008 with maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping sequence as control, *Sesbania* green manure, wheat straw and their combination to evaluate the influence of organic sources. The result showed that *Sesbania* green manure in combination with wheat straw followed by *Sesbania* green manure alone recorded significant improvement in system productivity (12.5 t/ha), protein content of maize (8.51%) and wheat (10.24%) and N, P and K uptake of both the crops and the system. Furthermore, addition of *Sesbania* green manure along with wheat straw improved the available N, P, K and organic carbon in soil to the tune of 25.3, 49.3, 5.9 and 11.9% over control, respectively.

Phullan et al. (2017) applied manures (control, farmyard manure, *Sesbania* and cluster bean) as main split and mineral fertilizer rates (control, 40-30, 60-45, 80-60, 90-70 and 120-90 kg N-P_2O_5/ha) as sub-split. The manures significantly influenced soil properties along with shoot dry weight, N, P and K uptake. Conversely, the rates of mineral fertilizers did not have any effect on soil properties, however, significantly enhanced the shoot dry weight and N, P and K uptake. The combined use of manures and mineral fertilizers had a significant effect on shoot P uptake.

Pawar et al. (2018) carried out an experiment to study the effect of various crop residues and green manure on soil properties and yield of cotton in salt affected soils of purna valley. The results of the experiment indicated that various green manure treatments significantly decreased the pH value over initial status, whereas electrical conductivity was increased under almost all the treatments over initial status. The bulk density and mean weight diameter was slightly improved with *Dhaincha* in situ green manure as compared with control. The application of in situ *Dhaincha* green manure significantly increased available N (249.90 kg/ha), P_2O_5 (30.46 kg/ha) and K_2O (459.20 kg/ha).

2.3 Probiotic inoculation and soil amendments

2.3.1 *Trichoderma* spp. inoculation for soil

Singh et al. (2010) applied *Trichoderma* multiplied culture (TMC) of *T. harzianum* strain Th 37 at the rate of 20 kg/ha on the stubbles at the ratoon initiation stage and observed increased the availability of nitrogen (N), phosphorus (P) and potassium (K) by 27, 65 and 44%, respectively. Some micronutrients *viz.* Cu, Fe, Mn and Zn were enhanced, respectively by 6, 100, 79 and 66% and a considerable increase in organic carbon (55%) with associated decrease in soil pH (6%). Guong et al. (2010) Evaluated the effect of organic amendment on improving soil properties with application of 10 t/ha sugarcane filter cake compost plus *Trichoderma* spp. and 20 t/ha of fresh *Tithonia diversifolia* in orange orchards. They used the above organic treatments with recommended inorganic fertilizer (250g N -200g P_2O_5 -120g K_2O/plant) to compare with usual farmer practice (628g N - 327g P_2O_5 -64g K_2O/plant). Soil analyses indicated that amendment with sugarcane filter cake compost (+ *Trichoderma* spp.) and fresh *Tithonia diversifolia* led to an increase soil organic matter content, available nitrogen and phosphorus, CEC, soil aggregate stability and reduced soil compaction ($p \leq 0.05$) compared with the farmers usual practice.

Suparno et al. (2016) aimed to evaluate the effectiveness of *Trichoderma* spp. isolates from tidal swamp fields against *Rhizoctonia solani*. The result of the study showed that *Trichoderma* spp. isolates from tidal swamp fields were suspected as *Trichoderma harzianum* and the isolates were able to decrease plant disease intensity caused by *Rhizoctonia solani* about 7.4%. As well, *Trichoderma* isolates contribute to the plant growth which are represented by the number of growing tiller per clump and plant height (12.2 cm) and increases the content of nitrogen, phosphor, potassium in soils and soil pH value. Tapke (2017) opined that the chemical form of pesticides and use of fertilizers is not only financially burdening the farmers but also reducing fertility of the soil. Natural farming which involves zero-budget agriculture practices is a better option than even organic farming production from a natural *Trichoderma* culture using solid state fermentation as well as in biofertilizer use in cotton, groundnuts, maize, caster chilies all are uses in natural *Trichoderma* bio-fertilizers. Several farmers are doing well by natural farming in contrast to those depending on fertilizers.

2.4 Chemical fertilizer and soil properties

Baque et al. (2006) conducted a pot trial under greenhouse condition in Bangladesh having three levels of potassium (low: 39.0 medium: 156 and high 312 kg/ha) and three levels of soil moisture, namely control (less than 25% depletion from the field capacity, FC), mild stress (more than37.5% depletion from FC) and severe stress (more than 50% depletion from FC). The result revealed that higher levels of K improved the dry matter production, yield and yield contributing characteristics of wheat with the irrespective levels of soil moisture. Besides this, uptake of N, P and K were also enhanced with the increasing levels of K especially under water stress condition.

Dubey et al. (2012) carried out complete soil analysis to establish the status of nutrients in district Sidhi during cropping season and after harvesting (for summer and *Kharif* 2010). The obtained result clearly showed that the application of recommended doses of N, P and K increased the crop yield and application of 100% NPK substantially improved the available NPK over its initial value thereby indicating significant contribution towards sustaining the soil health. However, the fertility of soil appears to be adversely affected due to the imbalanced use of nutrients, i.e. N, P or N alone indicates necessity of the use of balanced fertilizers for sustaining soil fertility and productivity of crops.

Zhong et al. (2014) conducted an experiment to determine the effects of N fertilizer applications on soil physical-chemical characters and maize grain yield. The results indicated that the soil bulk densities were increased, whereas the soil porosity, field capacity and values pH were decreased by N application at different stages. Furthermore, N application could increase the N contents of leaf and stem, whereas less or excess N application should not significantly improve maize yield.

Azizi et al. (2016) studied the effect of different levels of chemical fertilizers on soil health and yield of maize (*Zea may*s L.), where fertilizers were used in different levels as nitrogen (120, 90,50,0 kg/ha), phosphorus (60, 45,30,0 kg/ha), potassium (40, 30, 20, 0 kg/ha) are applied under sandy loam soil. The result showed that application inorganic fertilizers increased soil physical properties like bulk density and particle density, but some parameters of soil physical properties as pores space and EC decreased. It was also recorded that the application of chemical fertilizers in treatment T_1 (120 kg N/ha, 60 kg P/ha, 20 kg K/ha) improved nitrogen and available phosphorus was found more in T_5 (60 kg N/ha, 60 kg P/ha, 20 kg K/ha).

Singh et al. (2017) opined that continuous application of balanced chemical fertilizers either alone or in combination with FYM or lime for forty two years significantly improved available N, P and K, total carbon (CT) and labile carbon (CL) as compared to control and unbalanced use of fertilizers. They also stated that application of 100 percent NPK + FYM was more effective for increasing available N, P and K as compared to application of chemical fertilizers alone and continuous use of urea alone had the most deleterious effect on soil properties and productivity of both the crops.

Li et al. (2018) studied to explore the influence on soil physico-chemical properties under a 38-years long-term fertilization in a brown soil where soil samples (0-20 cm) were taken from the six treatments of the long-term fertilization trial in October 2016: no fertilizer (CK), N_1 (mineral nitrogen fertilizer), N_1P (mineral nitrogen and phosphate fertilizer), N_1PK (mineral nitrogen, phosphate and potassic fertilizer), pig manure (M_2), M_2N_1P (pig manure, mineral nitrogen and phosphate fertilizer). The results showed that the long-term application of chemical fertilizers reduced soil pH value, while the application of organic fertilizers increased pH value.

2.5 Organic amendments for wheat growth and yield

2.5.1 Non-leguminous crop residue incorporation

Rautaray et al. (2003) mentioned that application of rice straw 30 days before transplanting resulted in a higher number of panicles and grains per panicle. However, application of rice straw alone reduced the number of tillers but increased when applied in combination with *Sesbania rostrata*. Gurpreet et al. (2007) evaluated the effect of various combinations of green manure (GM), wheat straw (WS), rice straw (RS), farmyard manure (FYM) and urea alone (control) on physical and hydraulic properties of soil in a rice-wheat experiment (1988-2001) in India. With addition of GM to all these treatments; FYM + GM (0.59%), WS + GM (0.60%), WS + RS + GM (0.64%) and GM (0.47%), organic carbon content further increased significantly. Increased OC content of the soil in turn improved its aggregation status, infiltration rate and decreased the bulk density, dispersion ratio and soil strength correspondingly. The differences in yield of rice were not significant among urea, GM and WS applied alone or in combination. However, the highest yield produced FYM + GM + urea combination.

Singh et al. (2010) noted that incorporation of crop residues decreased bulk density (BD) and increased infiltration rate, WHC (water holding capacity), microbial population, soil fertility as compared to no residue treatment. They also concluded that the residue incorporation with NPK fertilizer resulted in the highest yield, nutrient uptake, improved residual soil fertility and soil microorganism's status. Polthanee et al. (2011) were undertaken a research with treatments consisted of (1) rice straw incorporation into the soil, (2) rice straw combined with cattle manure, (3) rice straw combined with bio-extracted fertilizer, (4) rice straw combined with cattle manure and bio-extracted fertilizer. The significant effect on plant height was found from the application of different types of organic fertilizer combined with rice straw. At harvest, total above ground dry weight and panicle number were significantly affected by the application of different types of organic fertilizer. The rice straw combined with cattle manure and bio-extract fertilizer gave the maximum panicle number. Maximum grain yields were recorded from rice straw combined with cattle manure but did not show any significant difference from the treatment of rice straw combined with cattle manure and bio-extracted fertilizer.

Dahri et al. (2018) assessed the influence of wheat straw incorporation and timing prior to seeding at 6 Mg/ha (S+), relative to no straw (S-), on maize (*Zea mays* L.) growth and yield parameters, as well as on soil characteristics. The soil organic matter showed a weakly significant ($0.05 \leq p \leq 0.06$) increase under straw amendment compared with S-. Some parameters like seedling emergence, plant height, cob length, the number of grain rows/plant and the number of grains/cob, as well as 1000-grain weight and yield were the highest under S+, and the lowest under S-.

Meena et al. (2018) conducted a field experiment at the 'Research farm' of Division of Agronomy, Indian Agricultural Research Institute, New Delhi, during 2014-2015 and 2015-2016 to study the growth parameter, yield and economies in maize-wheat-mung bean cropping system as influenced by crop residue and potassium management. During both the years, wheat was positively influenced by variable crop residue and potassium management at growth stages. The highest value of plant height, DMA, LAI, mean crop growth rate, net assimilation rate of wheat were noticed with treatment receiving fungal consortium incorporation which was statistically at par with crop residue incorporation. Similar results were also revealed for grain yield, straw yield and significant interaction grain yield in the mentioned years.

2.5.2 Leguminous residue incorporation

Bakht et al. (2009) evaluated the effects of residue retention, fertilizer N application and mung bean (*Vigna radiata*) on wheat in a mung bean-wheat sequence where associated treatments were- (a) crop residue retained (+ residue), (b) removed (- residue), (c) 120 kg N/ha applied to wheat, (d) 160 kg N/ha to maize and (e) no nitrogen applied under a crop rotation wheat with maize or wheat with mung bean. The experimental outcome was crop residues incorporation increased the wheat grain yield on average by 1.31 times and straw yield by 1.39 times and application of N fertilizer produced on average 1.59 times more grain and 1.77 times more straw yield of wheat over the 0 N kg/ha treatment.

Ali et al. (2009) evaluated the suitability of different sources of organic materials for integrated use with chemical fertilizers considering the treatment T_1: control, T_2: 70% NPKS, T_3: 100% NPKS, T_4: 70% NPKS + rice straw (RS) 5 t/ha, T_5: 70% NPKS + *Dhaincha* (DH) 15 t/ha, T_6: 70% NPKS + mung bean residue (MBR) 10 t/ha, T_7: 70% NPKS + cow dung (CD) 5 t/ha and T_8: 70% NPKS + poultry manure (PM) 3 t/ha. In this study they applied organic manure or crop residue to transplant *Aman* rice and their residual effects were observed in the following *Boro* rice and reported that total grain yield in the cropping pattern ranged from 5.14 t/ha in T_1 (control) treatment to 12.29 t/hain T_3 (100% NPKS) treatment and application 3 t/ha PM with 70% NPKS (T_8) produced the total yield of 12.09 t/ha followed by 11.59 t/ha in the treatment containing 10 t/ha MBR plus 70% NPKS (T_6).

Jan et al. (2011) studied the response of mung bean residue (0, 10, 20 and 30 Mg/ha), nitrogen levels (0, 25, 50 and 75 kg/ha) and their interaction on barley. They observed that 30 Mg/ha mung bean residue presented values as emergence/m^2 (50), plant height (109 cm), leaf area/tiller (106 cm^2), lodging score (5.55), termites attack (3.4%), grains/spike (67), biological yield (12.80 Mg/ha) and grain yield (2.32 Mg/ha) were significantly ($p \leq 0.05$) higher compared to other levels. Similarly plant height (110 cm), lodging score (5.29) and biological yield (13.75 Mg/ha) were higher at 75 kg/ha N compared to other levels of N and interaction between residue and nitrogen indicated that 10 Mg residue and 50 kg N/ha is recommended to achieve maximum net return under comparable conditions.

Polthanee et al. (2012**)** conducted a research to investigate the effect of different rates of organic fertilizers with or without mung bean crop residues incorporated into the soil after harvesting, on growth and yield of transplanted rice. The result indicated that incorporation of mung bean residue into the soil provided 3.2 t dry matter/ha containing

50.2 kg N, 9.8 kg P and 166.2 kg K/ha along with significant increased plant height and tiller number/hill. They also found that incorporation of mung bean residue produced an increase in rice grain yield over fallow treatment of 416 kg/ha (or 17%) and significantly increased panicle number/hill.

2.5.3 Cow dung incorporation

Matsi et al. (2003) stated that liquid cattle manure should be applied to soil in such a manner that would improve soil fertility and crop production without causing salinity problems or increasing NO_2 levels. A four years experiment with winter wheat showed that application of manure did not affect seed germination but resulted in a significant increase in dry biomass at two growth stages and grain yield relative to control and was similar to that of fertilizer treatments.

Ramesh et al. (2009) reported combined effect of cattle dung manure (CDM), poultry manure (PM), and vermicompost (VC) *vis-à-vis* mineral fertilizers tested in four cropping systems involving soybean, durum wheat, mustard, chickpea and isabgol. They were applied organic manures based on the N-equivalent basis and nutrient requirement of individual crop and found the grain yields of durum wheat and isabgol were higher in the treatment that received from a combination of CDM + VC + PM, whereas in mustard, CDM + PM and in chickpea, CDM + VC recorded the higher yields. Hossain (2011) reported that cow dung significantly influenced on the characters related to the growth, yield and yield contributing characters except plant height, panicle length and 1000-grain weight. The highest grain yield (5.49 t/ha) was obtained from 8 t/ha cow dung application which was statistically identical with 6 t/ha cow dung application but significantly differ from cow dung rates. The lowest grain yield (4.59 t/ha) was obtained from control treatment.

Hossaen et al. (2011) studied the efficacy of different organic manure and inorganic fertilizer on the yield and yield attributes of *Boro* rice (*Oryza sativa* L.). The experiment consisted of 8 treatments, T_0: Control, T_1: 100% $N_{100}P_{15}K_{45}S_{20}$ (recommended dose), T_2: 50% NPKS + 5 t/ha cow dung, T_3: 70% NPKS + 3 t/ha cow dung, T_4: 50% NPKS + 4 t/ha poultry manure, T_5: 70% NPKS + 2.4 t/ha poultry manure T_6: 50% NPKS + 5 t/ha vermicompost, T_7: 70% NPKS + 3 t/ha vermicompost. The highest number of effective tillers/hill (13.52), the longest panicle (24.59 cm), maximum number of total grain/plant (97.45), the highest weight of 1000-seeds (21.80 g), the maximum grain yield (7.30 t/ha) and straw yield (7.64 t/ha) was recorded from T_5, whereas the lowest number of effective tillers/hill (6.07), the shortest panicle (16.45 cm), the minimum total grain/plant (69.13), the lowest weight of 1000-seeds (16.73 g), the lowest grain yield (2.06 t/ha) and straw yield (4.63 t/ha) was observed from T_0.

Raj et al. (2014) mentioned that cow dung is very effective alternatives to chemical fertilizers by enhancing productivity in long term with maintaining the soil health and enhancing the microbial population. Cow dung manure and vermicompost increase soil organic matter content, and this leads to improved water infiltration and water holding capacity as well as an increased cation exchange capacity. It also enhances productivity of yield and minimizes the chances of bacterial and fungal pathogenic disease.

Taheri et al. (2017) conducted a field experiment to assess the impact of cow manure and vermicompost on the improvement of rice grain yield and quality in Rasht, Iran in 2015 and 2016. The experimental factors were as two cow manure (0, 10 and 20 t/ha) and vermicompost (0, 5 and 10 t/ha). The results revealed that the application of cow manure and vermicompost increased grain yield components such as the number of fertile tillers and the number of grain. The highest grain yield was obtained from the application of 30 t/ha cow manure + 10 t/ha vermicompost in the first year (3537 kg/ha) and in the second year (3958 kg/ha). Although the combined application of various rates of cow manure and vermicompost improved plant growth and nutrient uptake but the influence of vermicompost on the grain yield and quality was much stronger.

Khatun et al. (2018) carried out a field research to evaluate the growth, yield and yield attributes of aromatic rice (cv. Tulshimala) under the fertilization of cow dung (organic manure) and zinc (micronutrient). The increased the number of total tillers/hill, number of productive tillers/hill, panicle length (cm), grain yield/hill (g), straw yield/hill (g), grain yield (t/ha), straw yield (t/ha) and biological yields were produced over control by the application of different levels of cow dung and zinc fertilizers. Here the treatment combination 10 t/ha cow dung and 12 kg/ha $ZnSO_4$ produced the highest grain yield (2.79 t/ha) and straw yield (5.80 t/ha) over other treatments.

2.5.4 Compost incorporation

Garcia et al. (2008) stated that application of compost is one of the most effective amendments and it improves not only the physico-chemical properties like aeration, cation exchange capacity, buffer capacity or porosity, but biotic factors too. They also mentioned from a biological point of view, compost can positively affect microbial population and their enzymatic activities and stimulates the development of plants by means of the presence of growth factors. Ibrahim et al. (2008) investigated the impact of organic manure and compost on productivity of wheat (*Triticum aestivum* L. cv. Inqlab-91) in sandy clay loam soil. They stated that organic amendments had positive but variable effects. They also observed that the organic manures/pot application increased the wheat yield by 11.13 (105%) to 13.53 (128%) g relative to the control. The wheat plant height, number of tillers, spike length, straw yield, grain yield and 1000-grain weight all were statistically different from that of control. They concluded with the suggestion that crop productivity may be improved significantly by the application of various organic manures for a longer time.

Diacono and Montemurro (2009) stated that adding up of organic residues recurrently, particularly the composted ones, increased soil physical fertility, mainly by improving aggregate stability and decreasing soil bulk density and also crop yield increased by up to 250% by long-term applications of high rates of municipal solid waste compost. Stabilized organic amendments improve crop yield quality but not reduce it. Saini and Kumar (2014) conducted a field experiment during 2006-2007 to 2012-2013 in India with combined application of composts in maintaining the soil health and ensuring sustainability in crop productivity. During conversion to organic farming, for the first three years of study (2006-2008) the yields of maize were low, however, after the third year of study i.e. from 2009-2012 the yields were improved. Similarly, in the wheat-gram cropping system the wheat equivalent yields were low during 2006-2007 and 2007-2008 but thereafter, an impressive increase was observed due to the improvement of soil health in the form of nutrients and microbial status.

Imran et al. (2017) used organic sources of fertilization to attain sustainability in agricultural production and noticed that soil physico-chemical characteristics were greatly influenced by charcoal and compost combine application. They also obtained results from the study revealed that maximum number of tillers (331), maximum productive tillers (312), promising number of grain/spike (56) and 1000 grain weight (44.1 g) of wheat was recorded with combine application of compost and charcoal 5+5 Mg/ha, whereas highest biological yield (8710.2 kg/ha) and grain yield (4023.2 kg/ha) was noted with compost application at the rate of 10 Mg/ha as compared to control plot and other treatments. With charcoal application at the rate of 10 Mg/ha along with combined application of compost and charcoal and inorganic fertilizers presented the highest plant height (93.7 cm).

2.5.5 Vermicompost incorporation

Prasad et al. (2003) reported that application of organic manure mainly vermicompost at the rate of 5 t/ha was found beneficial and significantly increased the dry matter yield of maize. Dry matter production per plant, LAI and silking were significantly higher with the application of vermicompost at the rate of 5 t/ha along with poultry manure at the rate of 14 t and 10 t FYM/ha. Gowda et al. (2010) reported that application of vermicompost 3.8 t/ha + poultry manure 2.45 t/ha in wheat recorded significantly higher plant height (86.30 cm), number of leaves (60.10), 1000-grain weight (42.73 g) and seed yield (3043 kg/ha), vigor index (3223) and seedling dry weight (311.27 mg) compared to other treatments.

Gopinath et al. (2008) studied to evaluate the effects of three organic amendments on the yield and quality of wheat (*Triticum aestivum* L.) and on soil properties during transition to organic production. The organic amendments with composted farmyard manure (FYMC), vermicompost and lantana (*Lantana* spp.) compost-1 applied to soil at four application rates (60 kg N/ha, 90 kg N/ha, 120 kg N/ha and 150 kg N/ha). The grain yield of wheat from all organic amendments was markedly lower (36-65% and 23-54% less in the first and second year of transition, respectively) than with the mineral fertilizer treatment. Protein content of wheat grain was higher (85.9 kg/g) for mineral fertilizer treatment in the first year of transition but in the second year, there were no significant differences among the mineral fertilizer treatment and the highest application rate (150 kg N/ha) of three organic amendments.

Barlas et al. (2018) aimed to investigate the effects of increasing doses of vermicomposts combined to soil and peat on wheat (*Triticum vulgaris* L.) growth and nutrition. For this purpose, air dried soil and peat were mixed with three rates of vermicompost equivalent to 0% (control), 25% and 50% (v/v) combinations which was replicated three times. The data revealed that nutritional concentration of aerial parts was influenced significantly by the application of vermicompost in the growth media. This study suggests that the vermicompost use in plant production has a role as a source of nutrients for plant growth.

2.5.6 Poultry manure incorporation

Umanah et al. (2003) conducted a field trial to study the effect of different rates of poultry manure on the growth, yield components and yield of upland rice cv. Faro 43 in Nigeria, during the 1997 and 1998 early crop production seasons. The treatments comprised 0, 10, 20 and 30 t poultry manure/ha. There were significant differences in plant height, internodes length, number of tillers/hill, panicle number/stand, number of grains/panicle and dry grain yield. There was no significant variation among treatments for 1000-grain weight.

Silva et al. (2005) determined the possibilities of increasing crop yields and soil nutrients by combined application of organic manure (straw, cattle manure, poultry manure and compost) and chemical fertilizer under rice crop rotation in 2004 yala and 2004-2005 maha seasons. Results of the study revealed that higher crop growth and yield can be obtained by combining organic manures and chemical fertilizers. Among the organic manure and chemical fertilizer combinations tested, poultry manure + NPK showed the highest (493% in yaha and 256% in maha) and rice straw + NPK combination showed the lowest (361% in yaha and 145% in maha) grain yields and increase of soil nutrient status, respectively.

They concluded that the combined application of poultry manure and chemical fertilizer is better compared to the organic manure + NPK combinations in sustainable crop yield and soil nutrient status.

Parvez et al. (2008) carried out an experiment at the soil science field laboratory, Bangladesh Agricultural University, Mymensingh during *Aman* season of 2006 to evaluate the combined effects of poultry manure, cow dung, *Dhaincha* and fertilization the yield and nutrient uptake by BRRI *Dhan* 30. The treatment receiving 80% RFD (recommended fertilizer dose) with 3 t/ha poultry manure produced the higher grain yield 4.80 t/ha and straw yield 5.70 t/ha. The performance of manure may be rated in order of PM>DH>CD.

Enujeke (2013) evaluated the different rates of poultry manure as 0 t/ha, 10 t/ha, 20 t/ha and 30 t/ha for growing improved maize in Nigeria. The results obtained indicated that plants that received 30 t/ha of poultry manure were superior at 8 weeks after sowing in 2008 and 2009, with mean height of 209.3 cm, mean number of leaves of 13.1, mean leaf area of 682.6 cm^2, mean grain weight at 16 weeks after sowing of 2.14 t/ha and mean number of grains/cob is 518.4. Islam et al. (2014) applied different treatments such as T_0 (Control), T_1 [STB-CF (HYG)], T_2 [CD + STB-CF (HYG)], T_3 [PM + STB-CF (HYG)], T_4 [COM + STB-CF (COM)] and T_5 [FP (Farmers' practice)] to observe integrated effect of manures and fertilizers on the yield attributes as well as grain and straw yields of wheat. The treatment T_3 [PM + STB-CF (HYG)] produced the highest grain yield 4362 kg/ha (90.40% increase over control) and straw yield 5492 kg/ha (84.79% increase over control). The treatment T_3 comprising poultry manure in combination with chemical fertilizers on IPNS (Integrated Plant Nutrient System) basis was found to be the best combination of manures and fertilizers for obtaining the maximum yield and quality of wheat at BAU farm.

Uwah et al. (2014) studied the effect of four rates of poultry manure (PM) (0, 5, 10 and 15 t/ha) on soil chemical properties and agronomic performance of sweet maize (*Zea mays* L. Saccharata strut). PM significantly ($p \leq 0.05$) raised soil pH, organic matter (OM) content, total N, available P, exchangeable K, Ca, Mg and the effective cation exchange capacity (ECEC) status of soil. The 15 t/ha PM rate maximized sweet maize growth attributes, total dry matter (TDM) and grain yields and also hastened days to 50% tasseling and silking. On average over the two seasons, the application of 5, 10 and 15 t/ha PM rates increased TDM and grain yield by 9.11, 57.29 and 77.67%; and 52.32, 117.18 and 144.28%, respectively compared with the 0 t/ha PM rate.

Rasul et al. (2015) investigated the influence of different manures on some vegetative growth of wheat variety *Semito* during the winter growing season of 2013-2014. The treatments including T_1 = control, T_2 = 20 t/ha sheep manure, T_3 = 20 t/ha cow manure and T_4 = 20 t/ha poultry manure; using randomized complete block design (RCBD) with four replications. The results showed that the poultry manure is the most efficient one compared to sheep and cow manures. The values of grain yield, biological yield and grain protein content were 6.75 t/ha, 15.67 t/ha and 14.96%, respectively for poultry manure treatment.

Shah et al. (2017) studied the residual effect of organic N (poultry manure) and mineral N on maize crop in Pakistan during 2014-2015. Combined doses of N from both sources were 120 kg/ha applied to wheat crops alone and in different combinations making six treatments. From the treatment where 25% N applied from poultry manure + 75% from mineral N source applied to the previous wheat crop produced maximum grain/ear, 1000-grain weight, biomass and grain yield was obtained.

Mukhtiar et al. (2018) worked on the use of different organic manures for improving crop productivity and to select potential organic manure that improve crop productivity. The results revealed that plots receiving poultry manures have high spikes/m^2 (274), grains/spike (60), more 1000-grain weight (42.29 g), high biological yield (11435 kg/ha) and high grain yield (3996 kg/ha). Similarly, sheep manure had also great effect on wheat parameters such as higher emergence/m^2 (103), tillers/m^2 (308), plant height (104.50 cm), grains/spike (60) and similar 1000-grain weight compared to poultry manures (42.20 g). They also compared cattle and farmyard manure with legume residue and found them better but were found less important in improving wheat quality compared to poultry and sheep manure.

2.5.7 Green manure incorporation

Rajinder et al. (2000) studied the combined use of organic manure and fertilizer on yield and nutrient uptake by rice in rice-wheat cropping system. They observed that yield of rice increased 100% with recommended NPK, but replacement of 25 or 50% N with green manure, FYM or wheat straw generally gave similar yields. Mammad et al. (2011) used a spring wheat cultivar in an experiment and included five organic manures; green manure (GM), farmyard manure (FYM), poultry litter (PL), press mud (PM) and sewage sludge (SS) at the rate of 10 t/ha. Six different treatments were made with different combinations of these manures along with one treatment having recommended dose of NPK (150, 115 and 60 kg/ha NPK, respectively) and one control treatment with no fertilizer at all. The results indicated that the combination of GM + PL+ SS each 10 t/ha gave maximum economic yield (3.65 t/ha), which was 137% more from control. PL and SS each 10 t/ha followed by green manure should be used as organic manure in wheat crops.

Paul et al. (2014) studied the effect of plant nutrient recycling through crop residue management, green manure and fertility levels on yield attributes, a rice-wheat cropping system in India. The crop residue incorporation (CRI) with or without *Sesbania* green manure (SGM) significantly influenced the plant height, number of tillers/m^2, number of grains/panicle or /ear and 1000-grain weight. Rice and wheat mean yield revealed that CRI or crop residue burning (CRB) resulted in slightly greater yield over crop residue removal (CRR) treatment. The CRI + SGM treatment again showed significantly greater grain yields of 7.54 and 5.84 t/ha and straw yields of 8.42 and 6.36 t/ha in rice and wheat, respectively, over other crop residue management treatments. This messaged that crop residue management with *Sesbania* green manure practice could be a better option for nutrient recycling to sustain the crop productivity in India, China, Pakistan and Bangladesh.

Seufert et al. (2012) reported that organic farming is a system aimed at producing food with minimal harm to ecosystems, animals or humans. Analysis of data shows that overall organic yields are typically lower than conventional yields. Context, systems and site characteristics creates yield variation for instant organic yields is 5% lower (rain-fed legumes and perennials on weak acidic to weak-alkaline soils), 13% lower (when best organic practices are used) and 34% lower (when the conventional and organic systems are most comparable).

2.6 Probiotic inoculation for wheat growth and yield

2.6.1 *Trichoderma* spp. inoculation for wheat

Sliesaravicius and Altintas (2006) accomplished a field trial with biological agent *Trichoderma* spp. and concluded that the treated plots produced the highest healthy grains compared to untreated plots. The highest 1000-grain weight was measured under the plots where seeds were treated either alone or in combination with *T. harzianum* followed by foliar spray. Up to 52 g (Shatabdi variety) 1000-grain weight was obtained from the plot which received seed treatment in combination with *T. harzianum* + *Penicillium* spp. and foliar spray with *T. harzianum.* They also investigated that *Trichoderma* spp. increased the spike length, number of grains/spike, 1000-grain weight and ultimately the grain yield.

Pratibah et al. (2012) conducted an experiment on the growth promoting ability of *Trichoderma viride* in the popular wheat (*Triticum aestivum* L.) variety Raj 3765 at farmer's field through TIFA-DST project and was successfully demonstrated in two districts of Rajasthan *viz.* Jaipur and Kota belong to different agro ecological zones (AEZ). Rhizosphere competence along with its growth promotion effect on rootlets, tillers, weight of grains and grain yield were evaluated by using *Trichoderma* spp. at three of the crops *viz.* seed, flowering and pre-harvesting at the rate of 4 g/kg and 4 ml/L along with soil treatment with farmyard manure and formulation at the rate of 50:1 before sowing and has been observed that grain yield significantly increased after application of *Trichoderma* spp. as compared to control.

Doni et al. (2014) evaluated the effectiveness of seven isolates of *Trichoderma* spp. in rice to promote growth and increase physiological performance. This study indicated that all the *Trichoderma* spp. tested isolates increased several physiological processes of rice including net photosynthetic rate, stomatal conductance, transpiration, internal CO_2 concentration and water use efficiency. They concluded that beneficial fungi isolate

Trichoderma spp. SL2 has potential growth promoting ability of rice regarding plant height (70.47 cm), tiller number (12), root length (22.50 cm) and root fresh weight (15.21 g) compared to the plants treated with other *Trichoderma* spp.

Bokhtiar et al. (2015) conducted a research at Bangladesh to examine the effects of enriched compost with chemical fertilizers on soil fertility and productivity of sugarcane where four levels of inorganic fertilizers (100%, 75%, 50% and 0%) and four levels of pressmud (enriched by *Trichoderma harzianum* 7.5 t/ha, *T. viride* 7.5 t/ha, untreated raw pressmud 10 t/ha and control) were applied. It was observed that germination (90.34%), total chlorophyll content (2.58 mg/g), leaf area index (5.00), dry matter (3.41 kg/m^2), tiller (137.94 × 000 /ha), millable cane stalk (99.15 × 000/ ha) and yield (111.32 t/ha) were found maximum in 100% recommended fertilizer (N_{150} P_{50} K_{90} S_{35} and Zn_4 kg/ha) with enriched pressmud which was statistically identical in comparison with 75% and 50% of recommended chemical fertilizers with enriched pressmud. Finally, they concluded that enriched pressmud is more effective than raw pressmud in increasing sugarcane yield and maintaining soil fertility in High Ganges River Floodplain soils.

Hossain et al. (2016) worked with five different plant extracts including neem (*Azadirachta indica*), mehedi (*Lawsonia alba*), garlic clove (*Allium sativum*), rhizome of ginger (*Zingiber officinales*), seeds of black cumin (*Nigella sativa*), and BAU-Bio-fungicide (a *Trichoderma* based preparation) to evaluate the performance or effectiveness of those biological control agent on *Bipolaris* leaf blight of wheat and related pathogen (*Bipolaris sorokiniana*). Moreover, effect of seed treatment on wheat plant was evaluated and higher normal seedlings were found with BAU-Bio-fungicide, extracts of garlic clove and neem leaf at the value of 13%, 12% and 10%, respectively and BAU-Bio-fungicide also resulted 26.6% higher vigor index over control. They further reported that multiplication effect of seed treatment plus foliar spray showed superior effect by BAU-Bio-fungicide including higher 1000-grain weight (43.92 g) and grain yield (2.75 t/ha) which revealed that BAU-Bio-fungicide increased grain yield (29.87%) over control.

Hajieghrari and Mohammadi (2016) worked to observe the effect of five indigenous isolates (*T. harzianum* T 969, *T. harzianum* T 447, *T. hamatum* T 614, *Trichoderma* sp. isolate T and *Gliocladium virens* G525) on wheat variety (Moghan 3) seed germination, seedling vigor and plant growth through seeds treatment by the conidia and culture filtrate of the isolates. The result in overall, seed germination rate was increased and the highest seed germination rate (95.8%) was observed for *T. harzianum* T 969 non-sterilized cultural filtrate treatment. Furthermore, the field experiments showed that the isolates had significant effect on parameters such as 1000-grain weight, ear fresh and dry weights, ear length and stem and root dry weight.

Talukder et al. (2017) evaluated the efficacy of *Trichoderma* fortified compost with different substrates to reduce the pre-emergence and post-emergence seedling mortality, diseases of stem and root of chickpea. After the experiment, they stated that *Trichoderma* fortified compost with poultry manure was found significantly effective in reducing pre- emergence and post-emergence seedling mortality, disease incidence and disease severity of chickpeas in the field. Besides this, all the treatments significantly increased but *Trichoderma* fortified compost with poultry manure was the best to boost seed yield and quality.

Mahato et al. (2018) conducted a study to find out the effects of *Trichoderma viride* on growth and yield of wheat including of seven treatments (T) - T_1: Control, T_2: Soil + NPK, T_3: Soil inoculated *Trichoderma*, T_4: *Trichoderma* + FYM, T_5: *Trichoderma* + ½ NPK, T_6: *Trichoderma* + NPK and T_7 = *Trichoderma* + NPK + FYM. The results showed that *Trichoderma viride* increased the plant height (4.6%), root weight (1.5%), leaf length (0.3%), panicle weight (9.1%), number of grains (3.8%), grain yield (36.5%), biological yield (13.7%), and biomass yield (2.7%) over control. They also opined that when *T. viride* and NPK were accompanied with farmyard manure, most of the growth and yield parameters showed the highest value as more introducing farmyard manure to *T. viride* gives better yield than *T. viride* alone.

2.7 Chemical fertilizer for wheat growth and yield

Tarique and Paul (2005) carried out an experiment in order to evaluate the effects of different doses of nitrogen fertilizer on the yield of two wheat cultivars (Kanchan and Sourav) in the botanical field Rajshahi University, Bangladesh. In this study seven treatments were applied as T_0 = control, T_1 = 20 kg N/ha, T_2 = 40 kg N/ha, T_3 = 60 kg N/ha, T_4 = 80 kg N/ha T_5 = 100 kg N/ha and T_6 = 120 kg N/ha which presented that plant height, dry matter/plant, tiller/plant, panicle length, spikelet/panicle, 1000-grain weight, harvest index and grain yield of wheat increased significantly with the increase of nitrogen level and the rate 120 kg N/ha considered as most suitable for the above mentioned characters.

Alam et al. (2009) conducted a research to ascertain the effect of K application on wheat at district Pabna in Bangladesh during *Rabi* season. In this study five different levels of K were applied and the 36 kg K/ha showed the remarkable increase in grain, straw and total biomass yield of wheat. Here the highest protein content was recorded from 36 kg K/ha, which was 6.86% and 4.98% higher over omission of K and recommended dose (100% estimated K). Iqbal et al. (2012) investigated that the effect of seeding rates and different levels of nitrogen on yield and yield component of wheat by using cultivar Fareed-2006 at seeding rates of 125, 150 and 175 kg/ha with five nitrogen levels as 0, 75, 100, 125 and 150 kg N/ha. They noticed that the plant height, number of tillers/m^2, spike length, number of spikelet/spike, 1000-grain weight, grain yield, biological yield and harvest index were highest at nitrogen at 125 kg N/ha and lowest at 0 kg N/ha level of nitrogen.

Debnath et al. (2014) conducted a field trial in Bangladesh Agricultural University, Mymensingh from November 2011 to March 2012 to determine the effect of nitrogen (N) and boron (B) fertilization on the performance of wheat. The trial comprised of four levels of N *viz.* 0, 80, 120, 160 kg/ha and three levels of B *viz.* 0, 1 and 2 kg/ha where grain was found to be significantly and positively correlated with number of effective tillers/plant, number of fertile spikelet/spike, number of grains/spike and straw yield. The result also presented that wheat grain yield increased with increasing levels of N and B up to 120 kg/ha and 2 kg/ha, respectively.

Akhtar et al. (2018) conducted a field experiment entitled "Yield maximization through nutrient management in irrigated wheat (*Triticum aestivum* L.)" comprising ten treatments of nutrient management. The experimental soil was clayey in texture, medium in available N, P, K and low in available zinc where wheat variety (GW-336) was sown at 22.5 cm row spacing. The experimental results revealed that significantly higher values of growth parameters *viz.* plant height, dry matter/plant, number of total tillers and effective tillers, and yield attributes *viz.* length of spike, number of grains/spike, grain weight/spike and 1000-grain weight, higher grain yield (4227 kg/ha) and straw yield (5792 kg/ha), quality parameters *viz.* protein content and protein yield were recorded significantly higher under the treatment of RDF (120-60-60 kg N -P_2O_5- K_2O/ha) + $ZnSO_4$ 25 kg/ha.

Chapter III

Materials and Methods

3. MATERIALS AND METHODS

The present piece of research work was conducted at Plant Biotechnology and Genetic Engineering Laboratory, Institute of Biological Sciences and its experimental field and at Plant Pathology Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi during the period of July 2016 to June 2019 to study the sustainable improvement of wheat (*Triticum aestivum* L.) yield through soil amendments with probiotic and organic manures. In this chapter the details of different materials used and methodologies followed during the study are presented.

3.1 Description of the experimental site

3.1.1 Location

The experimental field is located at the western side of Rajshahi University, Bangladesh. Geographically situated at $24^0$17` N latitude and $88^0$28` E longitude at an elevation of 20 m above the sea level belonging to the Agro-Ecological Zone-11(AEZ-11).

3.1.2 Soil properties

The soil of the investigation plot has characteristics like poorly drained with moderately permeability, textural class loam and slightly alkaline in nature.

3.1.2.1 Physical properties

Moisture content (%)	PD (g/cc)	BD (g/cc)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	Textural class
19.40	2.65	1.27	51.34	47	40	13	Loam

3.1.2.2 Chemical properties

pH	Organic matter (%)	K cmol (+)/kg	Total N (%)	P (µg/g)	S (µg/g)	Zn (µg/g)	EC (µs/cm)	C:N
8.10	1.20	0.150	0.07	26.30	12.50	0.75	145	10:1

3.1.3 Climatic condition

The field experimental site was under subtropical monsoon having heavy precipitation during the month of April to October and insufficient rainfall during the month of November to March. During the experiment period monthly average highest temperature (28°C) and precipitation (133 mm) was recorded in the month of April to September, whereas lowest temperature (15°C) and no precipitation found in December to January. Generally, winter is cool and dry in Bangladesh. Some meteorological records regarding temperature, rainfall, relative humidity and sunshine hours during the research period are presented in Table 4 (Appendix).

3.2 Cropping season

Rabi, *Kharif-I* and *Kharif-II* are the major cropping seasons in Bangladesh. *Rabi* season covers the month of middle October to mid March, *Kharif-I* season covers from mid March to the end of June and *Kharif-II* season from early July to mid October. Green manure (*Sesbania rostrata)* was grown in the *Kharif-II* season, whereas wheat in the *Rabi* season in this study.

3.3 Cropping history of the experimental plot

The plots of the research field are commonly used for agronomic crop production. Before 2016, the field was engaged with barley cultivation for two years.

3.4 Experiment

To achieve the objectives of the study the designed experiment was conducted for the three uninterrupted years.

3.4.1 Factors and treatments

The following three wheat varieties and nine soil amendments were included in the experiment:

Factor A. Wheat varieties (V): 3

V_1 = BARI wheat-28

V_2 = BARI wheat-29

V_3 = BARI wheat-30

Factor B. Soil amendments (T): 9

T_0 = Control (without treatment)

T_1 = Rice straw + vermicompost + green manure

T_2 = Cow dung + vermicompost + green manure

T_3 = Compost + vermicompost + green manure

T_4 = Poultry manure + vermicompost + green manure

T_5 = *Trichoderma harzianum* + vermicompost + green manure

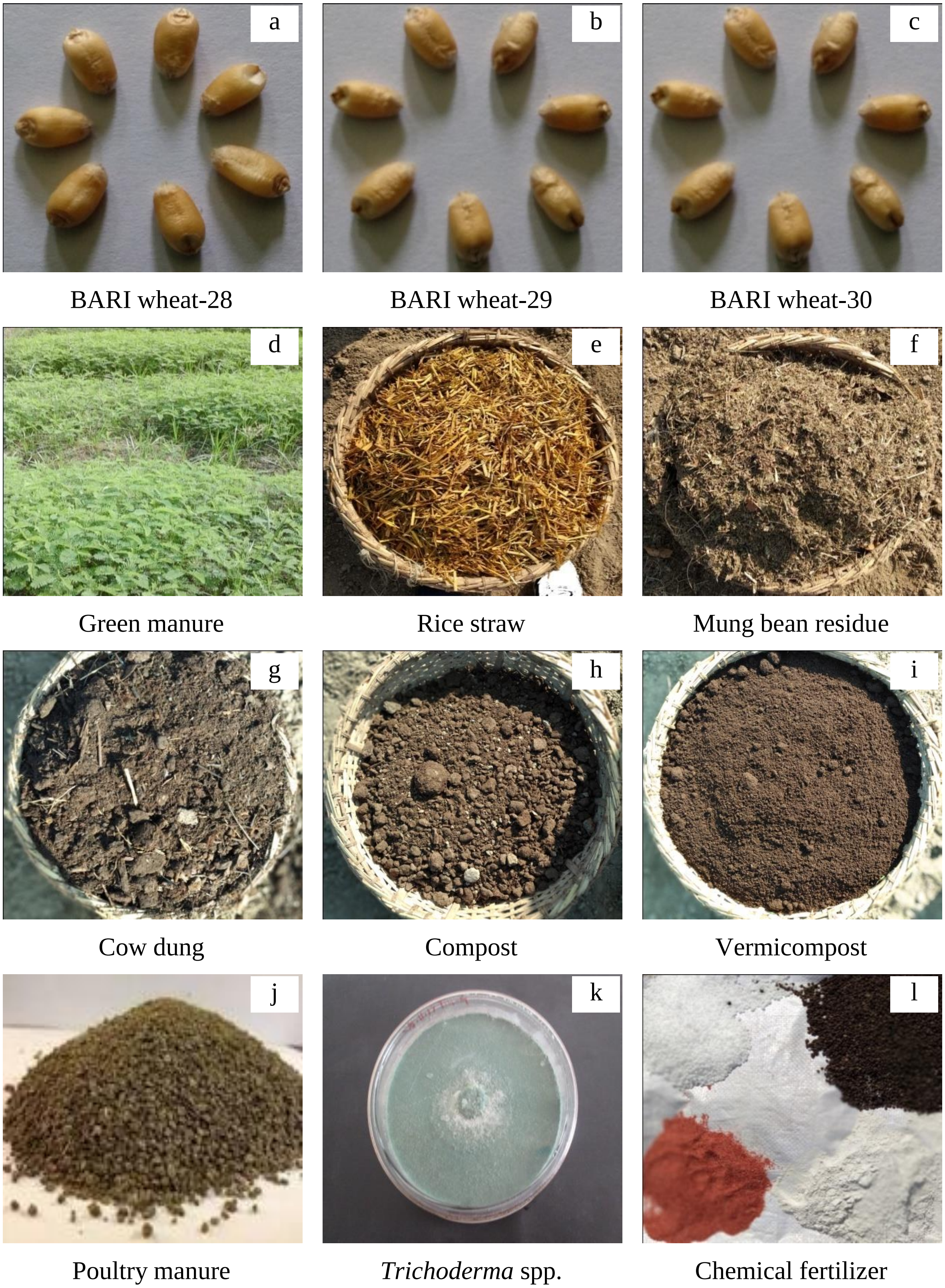
T_6 = Mung bean residue + vermicompost + green manure

T_7 = *Trichoderma viride* + vermicompost + green manure

T_8 = Chemical fertilizer (recommended dose)

3.4.2 Experimental design

The experiment was laid out in randomized complete block design (RCBD) with three replications. Each block was compacted with a 27 unit plot. Thus the total numbers of unit plots were 81. The unit plot was 2.5 m × 2.0 m = 5.0 m^2 having plot to plot 0.5 m and bed to bed distance 0.25 cm and 1m from surrounding the boundary. The unit plots were separated with earthen bunds to avoid nutrient transfer to besides plot by lateral seepage.



Figs. 1 (a-l): Different treatment materials used in the experiment.

3.4.3 Description of wheat varieties

Three modern wheat varieties namely BARI wheat-28, BARI wheat-29 and BARI wheat-30 were used as planting materials. All the varieties were developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Some features of these wheat varieties are given below:

Wheat variety ⇨ Wheat features ⇩	BARI wheat-28	BARI wheat-29	BARI wheat-30
Sowing time	November	November	November
Plant height	95-100 cm	98-100 cm	100-103 cm
No. of tillers/plant	4-5	4-5	4-5
Days of heading	55-60	62-65	60-65
Grains/spike	45-50	42-43	45-47
Grain color	White	White amber	White amber
1000 seed weight	43-48 g	42-45 g	43-45 g
Life length	102-108 days	105-110 days	100-105 days
Grain yield	4.0-4.5 t/ha	4.0-5.0 t/ha	4.5-5.0 t/ha
Released on	2012	2014	2014

3.4.4 Green manuring

3.4.4.1 Land preparation

For experimentation during the year 2016-2017, the land was opened on 01 August, 2016 by power tiller followed by two ladders. Then weeds and stubbles were removed from the field and according to the experimental design 81 unit plots were prepared.

3.4.4.2 Seed sowing

As per treatment specification on 05 August 2016, seeds of *Dhaincha* (*Sesbania rostrata*) were sown on the experimental plots using at the rate of 50 kg/ha (BARI 2014) following broadcast method.

3.4.4.3 Harvesting

After 50 days of sowing the young succulent green manure plants were cut into pieces and incorporated into the soil to the respective plots (Dubey et al. 2015). After mixing, light irrigation was applied and waited about 6 weeks for decomposition of the plant materials. These similar practices were continued for the next two consecutive cropping seasons 2017-2018 and 2018-2019.

3.4.5 Establishment and management of wheat crop

3.4.5.1 Land preparation

After complete decomposition of green manure, the experimental plots were ploughed for three times followed by laddering to have a good tilt on 09 November 2016. Later on, weeds and stubbles were removed from the plots. For the experimentation the above work was repeated for next two years (2017 and 2018).

3.4.5.2 Treatment application

Crop residues (rice straw, mung bean residue), cow dung, compost and poultry litter were applied at the rate of 10 t/ha before 15 days of sowing. Other manures like vermicompost and *Trichoderma* spp. were applied as dose of 5 t/ha and suspension (10^6 cfu/g at the rate of 5 kg/ha), respectively. Urea was applied at the rate of 200 kg/ha as three installments, first at final land preparation, second after first irrigation and third after second irrigation. All other fertilizers were applied as basal dose TSP 160 kg/ha, MP 45 kg/ha and Gypsum 115 kg/ha (BARI 2014) during final land preparation. Crop residues were collected from IBSc field laboratory. Cow dung and compost were collected from a trained farmers pit under DAE Bagatipara, Natore. Poultry litter was collected from a poultry farm. Vermicompost and chemical fertilizers were collected from Sumi Seed Vander, Rajshahi and *Trichoderma* spp. were cultured in Plant Pathology Laboratory, Agronomy and Agriculture Extension Department, University of Rajshahi, Bangladesh.

3.4.5.3 Collection of seed

Seeds of selected wheat varieties were collected from Regional Wheat Research Centre, Shyampur, Rajshahi, Bangladesh.

3.4.5.4 Seed sowing

In the 2016-2017 cropping year, wheat seeds were sown on 25 November 2016, likewise in the 2017-2018 and in 2018-2019 seeds were sown on 27 November 2017 and 25 November 2018. Seeds were sown in line following seed to seed and line to line distance 4 cm and 20 cm with a depth of about 4-5 cm opened by specially made an iron hand tine. The sown seeds were covered by soil manually. Seeds were applied as BARI recommended a dose 120 kg/ha. Bird boys were appointed for prevention from birds and other enemies during germination seeds and plant establishment.

3.4.5.5 Weeding

The major infesting weed species for wheat were *Chenopodium album, Cyperus rotundus* L., *Amaranthus spinosus* L. and *Cynodon dactylon* and weeds were controlled by hand weeding with niri for two times at 30 and 50 DAS.

3.4.5.6 Irrigation

Wheat crops were irrigated considering the presence of soil moisture. The crop provided 3 irrigations at crown root initiation (21 DAS), flowering (55 DAS) and grain filling (75 DAS) stages (BARI 2014). In every application flood method of irrigation was followed.

3.4.5.7 Harvesting and processing

After examining the proper maturity harvesting of crops was accomplished on 20 March 2017, 23 March 2018 and 25 March 2019, respective year of study. The harvested crop of each plot covering 1 m^2 was bundled individually, tagged properly and taken to the clean threshing floor. Then the crop was separately threshed, cleaned and winnowed for necessary data collection mentioned in the yield and yield contributing characters. Then grain yield and straw yield of each plot were recorded and the both yields were converted to hectare basis.

Prepared land | Seedling infection | Seedling blight

Sundry for oven dry | Oven dry | Booting stage

Panicle initiation | Crop at maturity | Bundle for data collection

Germinated seed | Soil collection | Data recording

Figs. 2 (a-l): Scenario of crop production and data collection.

3.4.6 Soil sample collection and analysis

3.4.6.1 Soil sample collection

Soil samples were collected randomly from nine places of the experimental field at the beginning of experimentation with the help of auger (SRDI 2017). Collected samples were packed in a polythene bag and were sent to the Department of Soil Science, Bangladesh Agricultural University, Mymensingh, for determination of moisture content, particle density and textural class.

3.4.6.2 Physical properties analysis

3.4.6.2.1 Moisture content

Moisture content of the soil is conveniently determined by gravimetric method. Soil samples (10 g each) were taken from a uniform depth. The fresh weight of the samples was recorded. Dry weight was determined after drying the soil in an oven for 24 hrs at 105°C to a constant weight, and the moisture percentage was calculated (Black 1965).

$$\text{Percent of moisture} = \frac{W_1 - W_2}{W_1} \times 100$$

Where, W_1 = weight of sample before drying and W_2 = weight of sample after oven drying.

3.4.6.2.2 Particle density

Twenty five gram oven dry soil was poured in 100 ml volumetric flask and added 50 ml water in the flask. Then boiled the flask for 20 minutes in a water bath and cooled. After that distilled water was flask to have a desired volume. Then was reweighed the flask and measured the temperature of water to determine the density of water. The differences of two weights gave the weight of water. The volume of water was determined by dividing the weight of water by the density of water. Then volume of soil was recorded from subtracting the volume of water from 100. The particle density was then expressed by the formula (Balck 1965).

$$\text{Particle density (Dp)} = \frac{\text{Ws}}{\text{Vs}}\ \text{g/cc}$$

Where, Ws = Weight of soil (g), Vs = Volume of solid soil (cc)

3.4.6.2.3 Bulk density and porosity

This method required a solid ring that pressed into the soil (Walter et al. 2016) to take an undisturbed core sample from 5-15 cm soil depth. Collected samples were dried at 105°C in an oven to get constant weights for 2-3 days depending on moisture content and then the mass of the dry soil sample was measured. The total volume of the soil sample was estimated as the internal volume of the core. The soil bulk density then was estimated as shown by the below formula (Yang et al. 2016).

$$\text{Bulk density} = \frac{\text{Weight of oven dry soil}}{\text{Total volume of soil}} \quad \text{g/cc}$$

Here, internal volume of core sampler (V) was calculated using the equation given below:

$$V = \pi r^2 h$$

Where, r is the radius of the core sampler and h is the height of the sampler.

The calculated bulk density to particle density and multiply by 100 gave the solid percentage of soil. Deduction of this result from 100 was presented the percentage of soil volume i.e. pore space or porosity as expressed by below formula:

$$\text{Porosity (\%)} = 100 - \frac{\text{Bulk Density}}{\text{Particle Density}} \times 100$$

3.4.6.2.4 Textural class

Hydrometer method was used to determine soil texture by estimating the soil particles i.e. sand, silt and clay percent as per Bouyoucos (1936). Fifty grams of oven dry soil sample was separately taken in a dispersion cup and added 10 ml 5% calgon solution as also added 90 ml distilled water to the cup then kept overnight. The suspension was then stirred with an electrical stirrer for 10 minutes. The content of the dispersion cup was then transferred to 1 liter sedimentation cylinder and distilled water was added to make the volume up to the mark. A cork was placed on the mouth of the cylinder and the cylinder was inverted several times until the whole soil mass appeared in the suspension. The cylinder was set upright and the hydrometer reading was taken at 40 seconds and 2 hrs of sedimentation.

The temperature of the suspension was also recorded with a thermometer at 40 seconds and 2 hrs of sedimentation. The correction of hydrometer reading was made as the hydrometer was calibrated at 68°F. The percentage of sand, silt and clay were calculated as follows:

$$\% \ (\text{Silt} + \text{Clay}) = \frac{\text{Corrected hydrometer reading after 40 seconds}}{\text{Weight of soil}} \times 100$$

$$\% \ \text{Clay} = \frac{\text{Corrected hydrometer reading after 2 hours}}{\text{Weight of soil}} \times 100$$

% Sand = 100 - % (Silt + Clay)

% Silt = % (Silt + Clay) - % Clay

The textural classes were determined by plotting the values of percentages of sand, silt and clay content on to the Marshall's Triangular Coordinate (Marshall 1947) following the USDA system.

3.4.6.2.5 Chemical analysis

For chemical analysis of soil samples were collected as mentioned in physical analysis. Here collected samples were air dried and powdered with a wooden roller. To remove coarse concretions, stones and organic debris each sample was passed through a 2 mm sieve. Then chemical properties mentioned pH, organic matter, N, P, K, Zn, EC and C:N was determined and analyzed at Soil Resource Development Institute (SRDI) Laboratory, Shyampur, Rajshahi, Bangladesh. Organic manures were also analyzed to determine nutrient elements content in the above mentioned institute shown in Table 3 (Appendix).

3.4.6.2.6 Soil pH

Soil pH was measured in 1:25 suspensions of soil and water on a glass electrode pH meter as outlined by Jackson (1962). Prior to making pH measurement, the electrode was calibrated using standard buffer solutions at pH 4.0 and 7.0

3.4.6.2.7 Organic matter

Organic carbon content of the soil was volumetrically determined by wet digestion method (Walkley and Black 1935). Organic matter was determined by multiplying organic carbon with Van Vemelon factor (1.724).

3.4.6.2.8 Total nitrogen

Total N in the soil was determined by the semi-micro Kjeldahl method. The sample was digested with concentrated sulphuric acid (H_2SO_4) and potassium sulphate (K_2SO_4) catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: se = 100:10:1). Nitrogen in the digest was determined by distilling the digest with 10 N NaOH solution followed by titration of the distilled trapped in H_3BO_3 indicator solution with 0.01 N H_2SO_4 (Bremner and Mulvaney 1982).

3.4.6.2.9 Available phosphorus

Phosphorus was extracted by shaking the soil with 0.5 M sodium bicarbonate solution having pH 8.5. The extractable P in solution was then determined colorimetrically at 882 nm wave length after developing blue color using molybdate-ascorbic acid (Olsen and Sommers 1982).

3.4.6.2.10 Exchangeable potassium

Exchangeable potassium was extracted with neutral 1 N NH_4OAc as described by Jackson (1973) and was measured by Atomic Absorption Spectrophotometer.

3.4.6.2.11 Available sulphur

The available sulphur content in the soil was extracted by 0.01 M $Ca(H_2PO_4)_2$. The extracted S was estimated turbid metrically and the turbidity was measured by spectrophotometer at 420 nm (Page et al. 1982).

3.4.6.2.12 Available zinc

The available zinc content in the soil was extracted with 0.05 M HCl and the concentration of Zn in the extract were measured directly by Atomic Absorption Spectrophotometer at 214 nm (Page et al. 1982).

3.4.6.2.13 Electrical conductivity

The EC of collected soil samples was determined electrometrically (1:5: Soil: Water ratio) by a conductivity meter using 0.01 M KCl solution to calibrate the meter following the procedure described by Ghosh et al. (1983). After harvesting wheat crop soil samples were immediately collected on 20 March 2017 regarding nine treatments each sample were analyzed to obtain relevant physical and chemical properties which were defined before cultivation of green manure. The mentioned three years experimental plot soils physical and chemical properties analysis was done in the above institutions.

3.4.7 Crop characters studied

3.4.7.1 Seedling infection

The seedlings which were found yellow and rotted at the base are considered as infected. From germination up to 14 days regular observation was made and infected seedlings were counted in each plot. Infection was estimated by the following formula:

$$\% \text{ Seedling infection } = \frac{\text{Number of infected seedlings}}{\text{Total number of seedlings}} \times 100$$

3.4.7.2 Seedling blight

Seedlings which were dead and became straw in color defined as seedling blight. Seedling infection is treated as the first step of seedling blight. Thus, blighted seedlings were counted at 21 DAS in every plot. It was estimated as by the following formula:

$$\% \text{ Seedling blight } = \frac{\text{Number of blighted seedlings}}{\text{Total number of seedlings}} \times 100$$

3.4.7.3 Leaf chlorophyll content

The atLeaf chlorophyll meter was used to assess leaf greenness. The meter determines light transmittance through the leaf at 660 and 940 nm wavelengths. The readings were obtained by inserting the middle portion of the topmost fully expanded leaf in the slit of the meter. At least three readings from leaves of randomly selected plants in each plot were recorded and mean value was determined. Abnormally looking or insect attacked plants were not selected for measurement (Ali et al. 2020).

3.4.7.4 Growth parameters of wheat

To explain the physiological basis of yield variation due to treatments, growth behavior of wheat was studied. Study of growth was started from 25 days after sowing (DAS) and ended at 85 DAS having a 15 days interval.

3.4.7.4.1 Total dry matter

In measurement of total dry matter (TDM) content, five plants were randomly collected from each plot at 25, 40, 55, 70 and 85 DAS. After collection of samples, the roots were cleaned with water to remove excess soil particles and kept in sun light to reduce moisture. The collected samples were then packed individually in labeled brown paper bags and were placed in an oven at 70-80°C for 72 hrs to get constant weight. After having constant weight each of them were measured with electrical balance and expressed as g/m^2.

3.4.7.4.2 Leaf area index and crop growth rate

For determination of leaf area index (LAI) five plants were also collected randomly from each plot at 25, 40, 55, 70 and 85 DAS as stated above. At each time, collected plants were separated into leaf, stem and spike (when appeared) and leaf area of the collected leaves was measured by disc method. To determine leaf area every leaf of each plant was segmented into three portions and the length and breadth of the middle portion of each leaf were recorded. Among the total leaves of a plant, each leaf was packed including three segments individually in a labeled brown paper bag and was placed in the oven to get constant weight for 72 hrs at 70-80°C. Then leaf area was calculated by applying the following formula:

$$\text{Area of leaf} = \frac{\text{Weight of leaves} \times \text{Area of segments}}{\text{Weight of segments}} \text{cm}^2$$

Leaf area index (LAI) and crop growth rate (CGR) were calculated by following the standard formulae as shown below (Radford 1967).

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area}}{\text{Ground area}}$$

$$\text{Crop growth rate (CGR)} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \text{g/m}^2\text{/d}$$

Here, W_2 and W_1 are the total dry weight plant at different DAS and t_2 and t_1 are the harvesting time at the latter and former respectively.

3.4.7.5 Yield and yield contributing characters of wheat

3.4.7.5.1 Plant height

Randomly five plants were selected from the harvested crop regarding each plot and treatments to measure the plant height. The height of the plant (cm) was measured from the base of the plant up to the tip of the upper most tip of the spike.

3.4.7.5.2 Total plant/m^2

Before harvesting 1 m^2 area was selected with quadrate and the number of total plants was counted. This operation was done in each plot preferably choosing the five rows in the middle of the plot.

3.4.7.5.3 Total tiller/plant

Tillers which had at least one leaf visible were counted from each plot that was collected with quadrate for representative area. It included both effective and non-effective tillers.

3.4.7.5.4 Effective tiller/plant

The numbers of tillers bearing panicles were counted at harvest with the help of quadrate from 1 m × 1 m area, which expressed as effective tillers/plant.

3.4.7.5.5 Awn length

Awn length (cm) was measured with scale from the representative samples at the end portion of top spikelet to the apex of glum.

3.4.7.5.6 Spike length

Five spikes were selected randomly from each plot and their length was measured from the neck node of the rachis to the apex of last grain of each spike without awn length and average length of spikes was expressed in cm.

3.4.7.5.7 Spikelet/spike

Five spikes were selected randomly to count the number of spikelet/spike at harvest from each plot and data was presented as number of spikelet/spike by calculating the average.

3.4.7.5.8 Fertile spikelet/spike

Presence of any food material in the spikelet was considered as a fertile spikelet present on each spike were counted and average value five of spike were recorded as collected from each plot.

3.4.7.5.9 Grains/spike

Presence of any food material in the spikelet was considered as grain and the total number of grains present on each spike was counted. Later on mean was calculated.

3.4.7.5.10 Deformed grains/spike

Misshaped grains were regarded as deformed grains/spike. Deform grains/spike was separated from total grains/spike and then average value was recorded on plot basis.

3.4.7.5.11 Grain weight/spike

Grain weight/spike is cumulative estimation of grains/spike and deforms grains/spike. This value was also average, estimated from sampled spike and expressed in gram (g).

3.4.7.5.12 1000-grain weight

One thousand grains were counted from grains of harvesting crops grown in one square meter area at the center of each treatment plot, dried properly and weighed (g) by using an electric balance.

3.4.7.5.13 Grain yield

Grain yields were determined by harvesting crops grown in one square meter area of each plot. The harvested samples were then threshed, dried and weighed by using balance and finally the values were expressed in t/ha.

3.4.7.5.14 Straw yield

After separation of grains from plants, the straw obtained from one square meter area of each unit plot was sun dried and weighed by using balance and finally these values were converted into t/ha.

3.4.7.5.15 Harvest index

It denotes the ratio of grain yield (economic yield) to biological yield and was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

$$= \frac{\text{Grain yield}}{(\text{Grain yield} + \text{Straw yield})} \times 100$$

Here, Biological yield = grain yield and straw yield.

3.4.8 Seed quality parameters of wheat

3.4.8.1 Germination

3.4.8.1.1 Germination media

90 mm glass petri dishes were taken for germination tests. Two thirds of each petri dish was filled up with sands and made saturated by water and then leveled. Four hundred seeds were taken for each treatment for germination as recommended by ISTA (1985). Twenty five seeds were set in each petri dish for germination test. The media were kept saturated for 10 days by adding water at one day interval.

3.4.8.1.2 Determination of germination

Data on germination of wheat seeds were collected regularly up to 10 days and after 10 days total number of germinated seeds was counted. Percentage of germination was determined as follows:

$$\text{Germination (\%)} = \frac{\text{No. of germinated seedling}}{\text{No. of seed set for germination}} \times 100$$

3.4.8.2 Vigor index

After setting seeds in petri dishes data were collected regularly from the beginning to the end of the experiment. Germination percentage was calculated from the final count. Vigor index was found out by using following formula (Maguire 1962):

$$\text{Vigor index} = \frac{\text{No. of normal seedlings (first count)}}{\text{Days to first count}} + ---------- + \frac{\text{No. of normal seedlings (final count)}}{\text{Days to final count}}$$

3.4.8.3 Total soluble protein content of wheat seed

A technique formerly defined by Guy et al. (1992) was performed with some modification to estimate the entire soluble protein using spectrophotometer. Initially, wheat seeds were taken from the respected samples. Then the samples were weighed and washed with cold distilled water. Afterwards the samples were crushed with mortar and pestle using ice cold buffer containing 0.04% (v/v) 2-mercaptoethanol, mM EDTA (ethylene di-amine tetra-acetic corrosive) and 50 mM Tris-HCl and buffer pH was fixed to 7.5. Then the sample solution was centrifuged for 12 minute at 10000 rpm at 25°C to remove the cell garbage. Afterwards the clear supernatants were separated in a glass cuvette and added 1 ml Coomassie Brilliant Blue (CBB) and measured the absorbance in a spectrophotometer (GENESYS 10S UV-Vis) at 595 nm. Finally, bovine serum albumin (BSA) calibration curve was applied to measure the total concentration of the sample's soluble protein.

3.4.9 Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. The trial data for all morphological and yield parameters were analyzed statistically for analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) (Gomez and Gomez 1984) was performed through r-studio (http://www.rstudio.com/) of "Agricolae" package (https://CRAN.R-project.org/package=agricolae). However, in case of mean comparison of soil parameters least significant difference (LSD) tests were used because of pairwise comparison such as 'Initial value versus 1st year value', '1st year value versus 2nd year value' and '2nd year value to 3rd year value'.

Chapter IV

Results

4. RESULTS

To achieve the objectives of the study various observations were completed. Some physical and chemical properties of soil and seedling viability, chlorophyll content, growth parameters, yield and yield contributing characters and seed quality of wheat were studied in this research. The collected data were analyzed statistically and presented in the form of tables, figures and appendices. Based on the above results detailed discussions are presented in this chapter.

4.1 Soil properties

4.1.1 Physical properties

4.1.1.1 Soil moisture

There was a significant influence of various soil amendments on soil moisture content in the year 2016-2017 (Table 1). Here the soil moisture content was found to be decreased significantly under all amendments except T_3. The highest rate of decrease (-3.33%) was found in the treatment T_8 (Chemical fertilizer). On the other hand, the least decrease in moisture content (-0.07%) was recorded in T_3 (Compost + vermicompost + green manure). As the consecutive year 2017-2018, soil moisture was varied by the application of different amendments. The treatment T_3 was demonstrated the higher increase of soil moisture (+0.60%) followed by T_2 (+0.40%), T_6 (+0.35%) and T_1 (+0.32%), whereas decline in soil moisture was found from T_0 (-1.27%) and T_8 (-1.80%). At the ending year of the study (2018-2019), the moisture content of soil was slightly increased for all the applied treatments except in T_0 (Control) and T_8. The most significant gain of soil moisture was recorded in T_3 (+0.87%) but major decline was found in T_8 (-2.13%) followed by T_0 (-2.00%).

Table 1: Changes of soil moisture content (%) as influenced by different soil amendments for three consecutive years of wheat production.

	2016-2017			2017-2018			2018-2019		
Treatment	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	19.40	16.73	-2.67*	16.73	15.47	-1.27*	15.47	13.47	-2.00*
T_1	19.40	17.85	-1.55*	17.85	18.17	$+0.32^{ns}$	18.17	18.65	$+0.48^{ns}$
T_2	19.40	18.65	-0.75*	18.65	19.05	$+0.40^{ns}$	19.05	19.77	+0.72*
T_3	19.40	19.33	-0.07^{ns}	19.33	19.93	$+0.60^{ns}$	19.93	20.80	+0.87*
T_4	19.40	17.33	-2.07*	17.33	17.57	$+0.23^{ns}$	17.57	17.93	$+0.37^{ns}$
T_5	19.40	17.10	-2.30*	17.10	17.27	$+0.17^{ns}$	17.27	17.53	$+0.27^{ns}$
T_6	19.40	18.05	-1.35*	18.05	18.40	$+0.35^{ns}$	18.40	18.95	$+0.55^{ns}$
T_7	19.40	16.90	-2.50*	16.90	16.98	$+0.08^{ns}$	16.98	17.20	$+0.22^{ns}$
T_8	19.40	16.07	-3.33*	16.07	14.27	-1.80*	14.27	12.13	-2.13*
LSD (0.05)		0.41			0.71			0.69	
CV (%)		1.30			2.40			2.40	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry Manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.1.2 Bulk density

In general, variation in bulk density of soil was recorded among the treatments in the whole study period (Table 2). There was a remarkable increase of soil bulk density under different soil amendments, the increase was pronounced (+0.05 g/cc) with T_8 treatment followed by T_0 (+0.03 g/cc). The decline trend was found in T_3 (-0.05 g/cc) followed by T_2, T_4 and T_6 in 2016-2017. Considering the differences between initial and final value of bulk density, the higher significant decrease was noted from T_3 with the value (-0.07 g/cc) oppositely higher significant increase was recorded from T_8 (+0.07 g/cc) during 2017-2018. Similar results were observed in the final year (2018-2019), where the greater significant deviation on bulk density was found in T_3 (-0.08 g/cc) but significant increase was found in T_8 (+0.10 g/cc) and in T_0 (+0.06 g/cc).

Table 2: Changes of soil bulk density (g/cc) as influenced by different soil amendments for three consecutive years of wheat production.

	2016-2017			2017-2018			2018-2019		
Treatment	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	1.27	1.30	+0.03^{ns}	1.30	1.34	+0.04^{ns}	1.34	1.41	+0.06*
T_1	1.27	1.24	-0.03^{ns}	1.24	1.21	-0.03^{ns}	1.21	1.17	-0.04^{ns}
T_2	1.27	1.23	-0.04*	1.23	1.20	-0.03^{ns}	1.20	1.15	-0.05^{ns}
T_3	1.27	1.22	-0.05*	1.22	1.16	-0.07*	1.16	1.08	-0.08*
T_4	1.27	1.24	-0.04*	1.24	1.18	-0.05^{ns}	1.18	1.14	-0.04^{ns}
T_5	1.27	1.24	-0.03^{ns}	1.24	1.21	-0.04^{ns}	1.21	1.17	-0.03^{ns}
T_6	1.27	1.24	-0.04*	1.24	1.20	-0.04^{ns}	1.20	1.15	-0.05^{ns}
T_7	1.27	1.25	-0.02^{ns}	1.25	1.24	-0.01^{ns}	1.24	1.20	-0.03^{ns}
T_8	1.27	1.32	+0.05*	1.32	1.39	+0.07*	1.39	1.49	+0.10*
LSD (0.05)		0.03			0.05			0.05	
CV (%)		1.30			2.30			2.50	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.1.3 Particle density

The particle density of soil did not differ significantly by the activities of various soil amendments all over the research period (Table 3). From the records of soil analysis in 2016-2017, the particle density remained unchanged at the T_0 (+0.00 g/cc) but the lowest decrease (-0.01 g/cc) was reported by T_1, T_5 and T_7. The + 0.01 g/cc was the only positive value of particle density noticed in T_8. There were no significant changes of particle densities observed from the applied treatments. But the treatment T_0 (+0.01 g/cc) and T_8 (+0.02 g/cc) demonstrated slight enhancement over initial value in 2017-2018. Without major variation the particle density remained unchanged in 2018-2019, where T_3 had the minimum decrease of particle density (-0.02 g/cc) which had the equality with T_1, T_2 and T_5.

Table 3: Changes of soil particle density (g/cc) as influenced by different soil amendments for three consecutive years of wheat production.

	2016-2017			2017-2018			2018-2019		
Treatment	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	2.65	2.65	+0.00 ^{ns}	2.65	2.66	+0.01 ^{ns}	2.66	2.67	+0.01 ^{ns}
T_1	2.65	2.64	-0.01 ^{ns}	2.64	2.63	-0.01 ^{ns}	2.63	2.61	-0.02 ^{ns}
T_2	2.65	2.63	-0.02 ^{ns}	2.63	2.63	-0.01 ^{ns}	2.63	2.61	-0.02 ^{ns}
T_3	2.65	2.63	-0.02 ^{ns}	2.63	2.61	-0.02 ^{ns}	2.61	2.61	-0.02 ^{ns}
T_4	2.65	2.63	-0.02 ^{ns}	2.63	2.61	-0.02 ^{ns}	2.61	2.60	-0.01 ^{ns}
T_5	2.65	2.64	-0.01 ^{ns}	2.64	2.63	-0.01 ^{ns}	2.63	2.61	-0.02 ^{ns}
T_6	2.65	2.63	-0.02 ^{ns}	2.63	2.61	-0.02 ^{ns}	2.61	2.60	-0.01 ^{ns}
T_7	2.65	2.64	-0.01 ^{ns}	2.64	2.62	-0.02 ^{ns}	2.62	2.61	-0.01 ^{ns}
T_8	2.65	2.66	+0.01 ^{ns}	2.66	2.68	+0.02 ^{ns}	2.68	2.70	+0.02 ^{ns}
LSD (0.05)		0.02			0.03			0.03	
CV (%)		0.40			0.60			0.70	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.1.4 Soil porosity

All the applied soil amendments showed significant differences in respect of soil porosity in the experimental period 2016-2017 (Table 4). Here among the treatments, the maximum decrease of soil porosity (-0.96%) was obtained from T_8, though the maximum increase was reported by T_3 (+2.16%) and then T_2 (+1.92%). As the consecutive year 2017-2018, the treatments demonstrated increase in porosity except T_7 (-0.05%), T_0 (-1.36%) and T_8 (-2.24%). There the maximum porosity was obtained from T_3 (+2.31%) oppositely the minimum porosity was observed in T_1 (+0.99%). After three years of study, the significant increase of soil porosity (+2.83%) was recorded in T_3 but the most significant decrease (-3.40%) was noted in T_8.

Table 4: Changes of soil porosity (%) as influenced by different soil amendments for three consecutive years of wheat production.

	2016-2017			2017-2018			2018-2019		
Treatment	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	51.34	50.94	-0.40*	50.94	49.58	-1.36 ^{ns}	49.58	47.37	-2.21*
T_1	51.34	52.91	+1.57*	52.91	53.90	+0.99 ^{ns}	53.90	55.00	+1.09 ^{ns}
T_2	51.34	53.26	+1.92*	53.26	54.29	+1.03 ^{ns}	54.29	55.93	+1.64 ^{ns}
T_3	51.34	53.50	+2.16*	53.50	55.80	+2.31*	55.80	58.74	+2.83*
T_4	51.34	52.98	+1.64*	52.98	54.73	+1.76*	54.73	56.33	+1.63 ^{ns}
T_5	51.34	52.82	+1.48*	52.82	54.15	+1.33 ^{ns}	54.15	54.98	+0.83 ^{ns}
T_6	51.34	53.04	+1.70*	53.04	54.29	+1.25 ^{ns}	54.29	55.81	+1.52 ^{ns}
T_7	51.34	52.84	+1.50*	52.84	52.79	-0.05 ^{ns}	52.79	53.81	+1.02 ^{ns}
T_8	51.34	50.38	-0.96*	50.38	48.14	-2.24*	48.14	44.74	-3.40*
LSD (0.05)		0.02			1.74			1.92	
CV (%)		1.20			2.00			2.20	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.1.5 Soil sand particle

The changes in soil sand particles showed a decreasing trend due to practicing different organic amendments during 2016-2017 (Table 5). Although most of the treatments showed insignificant variation but the significant variation of sand particles occurred in T_8 (+1.33%). Furthermore, the decrease of sand particles was recorded by T_2 and T_3. There was a similar trend of change of sand particles in the consecutive year 2017-2018. Here the maximum increase was noted from T_8 (+1.67%) and oppositely minimum from T_3 (-1.67%). Most of the values regarding sand particles of soil were affected by various soil amendments in 2018-2019. Likewise the previous year, T_8 was also increased (+2.00%) over the initial one followed by T_0 (+1.33%). Whereas the maximum decrease of sand particles were recorded from T_3 (-2.33%) followed by T_2 (-2.00%).

Table 5: Changes of soil sand particle (%) as influenced by different soil amendments for three consecutive years of wheat production.

	2016-2017			2017-2018			2018-2019		
Treatment	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	47.00	48.00	+1.00^{ns}	48.00	49.33	+1.33^{ns}	49.33	50.67	+1.33^{ns}
T_1	47.00	46.33	-0.67^{ns}	46.33	46.00	-0.33^{ns}	46.00	45.00	-1.00^{ns}
T_2	47.00	46.00	-1.00^{ns}	46.00	44.67	-1.33^{ns}	44.67	42.67	-2.00*
T_3	47.00	46.00	-1.00^{ns}	46.00	44.33	-1.67*	44.33	42.00	-2.33*
T_4	47.00	46.67	-0.33^{ns}	46.67	46.00	-0.67^{ns}	46.00	44.67	-1.33^{ns}
T_5	47.00	46.67	-0.33^{ns}	46.67	46.00	-0.67^{ns}	46.00	45.00	-1.00^{ns}
T_6	47.00	46.33	-0.67^{ns}	46.33	46.00	-0.33^{ns}	46.00	44.67	-1.33^{ns}
T_7	47.00	46.67	-0.33^{ns}	46.67	46.33	-0.33^{ns}	46.33	45.33	-1.00^{ns}
T_8	47.00	48.33	+1.33*	48.33	50.00	+1.67*	50.00	52.00	+2.00*
LSD (0.05)		1.01			1.51			1.60	
CV (%)		1.30			2.00			2.10	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.1.6 Soil silt particle

The influence of various soil amendments on soil silt particles was found to be increased in the year 2016-2017 (Table 6). The highest significant rate of increase was found in the treatment T_3 (+1.67%). On the contrary, the significantly highest decrease in silt particle (-2.00%) was recorded from T_8. As the repeated year 2017-2018, the treatments T_3 (+2.00%), T_2 (+1.67%) and T_4 (+1.33%) were demonstrated the higher increase of soil silt particles. Where, the greater deviations in silt particles over initials were found from T_8 (-2.67%) and T_0 (-2.33%). At the final year of the research, the result presented that the silt particle of soil was slightly increased for all the applied treatments except T_0 and T_8. The most significant achievement of the silt particle was recorded with T_3 having value +2.67%. But compared to initial value, significant decline of silt particles was found in T_8 (-3.00%) and T_0 (-2.67%).

Table 6: Changes of soil silt particle (%) as influenced by different soil amendments for three consecutive years of wheat production.

	2016-2017			2017-2018			2018-2019		
Treatment	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	40.00	38.67	-1.33*	38.67	36.33	-2.33*	36.33	33.67	-2.67*
T_1	40.00	41.00	+1.00 ^{ns}	41.00	42.00	+1.00 ^{ns}	42.00	43.67	+1.67 ^{ns}
T_2	40.00	41.33	+1.33*	41.33	43.00	+1.67 ^{ns}	43.00	45.33	+2.33*
T_3	40.00	41.67	+1.67*	41.67	43.67	+2.00*	43.67	46.33	+2.67*
T_4	40.00	40.67	+0.67 ^{ns}	40.67	42.00	+1.33 ^{ns}	42.00	44.00	+2.00*
T_5	40.00	40.67	+0.67 ^{ns}	40.67	41.67	+1.00 ^{ns}	41.67	43.00	+1.33 ^{ns}
T_6	40.00	41.00	+1.00 ^{ns}	41.00	42.00	+1.00 ^{ns}	42.00	44.00	+2.00*
T_7	40.00	40.33	+0.33 ^{ns}	40.33	41.00	+0.67 ^{ns}	41.00	42.00	+1.00 ^{ns}
T_8	40.00	38.00	-2.00*	38.00	35.33	-2.67*	35.33	32.33	-3.00*
LSD (0.05)		1.20			1.85			1.91	
CV (%)		1.80			2.80			2.80	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.1.7 Soil clay particle

In general, insignificant variation of clay particles of soil was recorded among the treatments in 2016-2017 (Table 7). There was a decrease of clay particles under different soil amendments but the increase was pronounced with T_8 (+0.67%) and in T_0 (+0.33%). The treatment T_3 showed the maximum decrease (-0.67%) on this parameter. Considering the differences between initial and final value of clay particles, the higher increase was noted from T_8 and T_0 with the equal value +1.00% during 2017-2018. Whereas the maximum decrease of clay particles was recorded in T_1, T_4 and T_6 with the value -0.67%. Similar results with insignificant change rate were observed in final year compare with the second year, where the greater difference on clay particle was found in T_1, T_4 and T_6 having the similar value -0.67% though parallel increase was noted from T_0 (+1.33%) and T_8 (+1.00%).

Table 7: Changes of soil clay particle (%) as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	13.00	13.33	+0.33 ^{ns}	13.33	14.33	+1.00 ^{ns}	14.33	15.67	+1.33 ^{ns}
T_1	13.00	12.67	-0.33 ^{ns}	12.67	12.00	-0.67 ^{ns}	12.00	11.33	-0.67 ^{ns}
T_2	13.00	12.67	-0.33 ^{ns}	12.67	12.33	-0.33 ^{ns}	12.33	12.00	-0.33 ^{ns}
T_3	13.00	12.33	-0.67 ^{ns}	12.33	12.00	-0.33 ^{ns}	12.00	11.67	-0.33 ^{ns}
T_4	13.00	12.67	-0.33 ^{ns}	12.67	12.00	-0.67 ^{ns}	12.00	11.33	-0.67 ^{ns}
T_5	13.00	12.67	-0.33 ^{ns}	12.67	12.33	-0.33 ^{ns}	12.33	12.00	-0.33 ^{ns}
T_6	13.00	12.67	-0.33 ^{ns}	12.67	12.00	-0.67 ^{ns}	12.00	11.33	-0.67 ^{ns}
T_7	13.00	13.00	+0.00 ^{ns}	13.00	12.67	-0.33 ^{ns}	12.67	12.67	+0.00 ^{ns}
T_8	13.00	13.67	+0.67 ^{ns}	13.67	14.67	+1.00 ^{ns}	14.67	15.67	+1.00 ^{ns}
LSD (0.05)		1.54			2.33			2.24	
CV (%)		7.20			11.00			10.60	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.1.8 Soil textural class

Textural class is output of the combination of soil particles in a particular soil. This parameter is a vital remark of soil type which affected the selection of soil for its utilization. The initial composite soil texture was reported as loam by analysis at the beginning of the study. The application of different soil amendments did not change the textural classes in the consecutive three years study (Table 8). Though it had no differences in the textural class all over the study period, there were variations in the percentage of different aforesaid soil particles.

Table 8: Changes of soil textural class as influenced by different soil amendments for three consecutive years of wheat production.

Treat.	2016-2017				2017-2018				2018-2019			
	Sand (%)	Silt (%)	Clay (%)	Textural class	Sand (%)	Silt (%)	Clay (%)	Textural class	Sand (%)	Silt (%)	Clay (%)	Textural class
T_0	48.00	38.67	13.33	Loam	49.33	36.33	14.33	Loam	50.67	33.67	15.67	Loam
T_1	46.33	41.00	12.67	Loam	46.00	42.00	12.00	Loam	45.00	43.67	11.33	Loam
T_2	46.00	41.33	12.67	Loam	44.67	43.00	12.33	Loam	42.67	45.33	12.00	Loam
T_3	46.00	41.67	12.33	Loam	44.33	43.67	12.00	Loam	42.00	46.33	11.67	Loam
T_4	46.67	40.67	12.67	Loam	46.00	42.00	12.00	Loam	44.67	44.00	11.33	Loam
T_5	46.67	40.67	12.67	Loam	46.00	41.67	12.33	Loam	45.00	43.00	12.00	Loam
T_6	46.33	41.00	12.67	Loam	46.00	42.00	12.00	Loam	44.67	44.00	11.33	Loam
T_7	46.67	40.33	13.00	Loam	46.33	41.00	12.67	Loam	45.33	42.00	12.67	Loam
T_8	48.33	38.00	13.67	Loam	50.00	35.33	14.67	Loam	52.00	32.33	15.67	Loam

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer.

4.1.2 Chemical properties

4.1.2.1 Soil pH

Soil pH was not significantly influenced by various soil amendments during the research period (Table 9). The increment of soil pH was noted higher (+0.13 unit) in T_8 and the (+0.10 unit) in T_4 in 2016-2017. While the least decrease (-0.07 unit) of pH was observed in T_2 and T_6 and remains unchanged in $T_{1,}$ T_5 and T_7. In the year 2017-2018, the pH was decreased by most of the treatments except T_0, T_4 and T_8. There the bigger increase (+0.13 unit) of pH was found in T_8 but the minimum equal losses (-0.03 unit) were noticed in T_5 and T_7. Although there was insignificant variation among the treatments in 2018-2019, however, the treatment T_8 was maintained the highest increment (+0.17 units). On the other hand, the maximum decrease (-0.10 unit) was recorded from T_2 and T_3.

Table 9: Changes of soil pH as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	8.10	8.17	+0.07 ns	8.17	8.20	+0.03 ns	8.20	8.27	+0.07 ns
T_1	8.10	8.10	+0.00 ns	8.10	8.03	-0.07 ns	8.03	7.97	-0.07 ns
T_2	8.10	8.03	-0.07 ns	8.03	7.93	-0.10 ns	7.93	7.83	-0.10 ns
T_3	8.10	8.00	-0.10 ns	8.00	7.87	-0.13 ns	7.87	7.77	-0.10 ns
T_4	8.10	8.20	+0.10 ns	8.20	8.27	+0.07 ns	8.27	8.30	+0.03 ns
T_5	8.10	8.10	+0.00 ns	8.10	8.07	-0.03 ns	8.07	8.00	-0.07 ns
T_6	8.10	8.03	-0.07 ns	8.03	7.93	-0.10 ns	7.93	7.87	-0.07 ns
T_7	8.10	8.10	+0.00 ns	8.10	8.07	-0.03 ns	8.07	8.03	-0.03 ns
T_8	8.10	8.23	+0.13 ns	8.23	8.37	+0.13 ns	8.37	8.53	+0.17 ns
LSD (0.05)		0.15			0.21			0.17	
CV (%)		1.10			1.60			1.30	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.2.2 Soil organic matter

Most of the cases soil organic matter content was improved by different soil amendments in the season 2016-2017. Significantly the major deviation (-0.12%) was noticed in T_8 then in T_0 (-0.10%), while major accumulation was recorded in T_3 (+0.04%) followed by T_2 (+0.03%). There was a trend of enhancement of soil organic matter by most of the amendments in 2017-2018. Where the greater significant increase (+0.06%) of organic matter content was observed in T_3 and considering the same parameter, the maximum significant decline (-0.15%) was noted from T_8. Organic matter content of soil after completion of three years trial under different soil amendments followed a similar movement as in 2017-2018. The treatment T_3 greatly improved organic matter status of soil (+0.14%) but T_8 showed significant decline (-0.17%) of organic matter content of soil (Table 10).

Table 10: Changes of soil organic matter content (%) as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	1.20	1.10	-0.10*	1.10	0.98	-0.12*	0.98	0.85	-0.13*
T_1	1.20	1.21	+0.01^{ns}	1.21	1.25	+0.04^{ns}	1.25	1.31	+0.06*
T_2	1.20	1.23	+0.03^{ns}	1.23	1.28	+0.05^{ns}	1.28	1.39	+0.11*
T_3	1.20	1.24	+0.04^{ns}	1.24	1.29	+0.06*	1.29	1.43	+0.14*
T_4	1.20	1.22	+0.02^{ns}	1.22	1.27	+0.05^{ns}	1.27	1.36	+0.09*
T_5	1.20	1.21	+0.01^{ns}	1.21	1.24	+0.03^{ns}	1.24	1.28	+0.04^{ns}
T_6	1.20	1.22	+0.02^{ns}	1.22	1.26	+0.04^{ns}	1.26	1.33	+0.08*
T_7	1.20	1.20	+0.00^{ns}	1.20	1.21	+0.01^{ns}	1.21	1.25	+0.03^{ns}
T_8	1.20	1.08	-0.12*	1.08	0.93	-0.15*	0.93	0.76	-0.17*
LSD (0.05)		0.05			0.05			0.04	
CV (%)		2.40			2.70			1.80	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.2.3 Total nitrogen

At the beginning of the study, i.e. in 2016-2017, due to application of different soil amendments resulted decrease of total nitrogen content of the experimental plots. The maximum significant loss of nitrogen (-0.025%) was observed in T_0 but a minor non-significant decrease was noticed in T_5 (-0.001%). Negligible differences of total nitrogen over initial were recorded by most of the treatments in 2017-2018. The treatment T_4 exhibited the greater significant increase of nitrogen (+0.016%), while T_0 (-0.015%) and T_8 (-0.011%) had the decreasing trend. In the last year, treatments T_4 and T_3 were showed the maximum significant gain in total nitrogen with the value +0.013% and +0.010%. Furthermore, soil total nitrogen was reduced (-0.015%) under the treatment T_8 (Table 11).

Table 11: Changes of soil total nitrogen (%) as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	0.070	0.045	-0.025*	0.045	0.031	-0.015*	0.031	0.022	-0.010*
T_1	0.070	0.051	-0.019*	0.051	0.054	+0.001 ^{ns}	0.054	0.056	+0.003 ^{ns}
T_2	0.070	0.057	-0.014*	0.057	0.061	+0.005*	0.061	0.068	+0.007*
T_3	0.070	0.063	-0.008*	0.063	0.069	+0.007*	0.069	0.079	+0.010*
T_4	0.070	0.068	-0.002 ^{ns}	0.068	0.084	+0.016*	0.084	0.097	+0.013*
T_5	0.070	0.070	-0.001 ^{ns}	0.070	0.076	+0.006*	0.076	0.084	+0.008*
T_6	0.070	0.056	-0.015*	0.056	0.058	+0.003 ^{ns}	0.058	0.062	+0.005*
T_7	0.070	0.066	-0.004*	0.066	0.070	+0.004 ^{ns}	0.070	0.075	+0.005*
T_8	0.070	0.050	-0.020*	0.050	0.039	-0.011*	0.039	0.024	-0.015*
LSD (0.05)		0.003			0.004			0.003	
CV (%)		3.100			3.800			2.700	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.2.4 Exchangeable potassium

In 2016-2017, exchangeable potassium (K) was significantly influenced under various soil amendments (Table 12). Data revealed that K was distinctly depleted under all the treatments with the maximum depletion in T_0 (-0.063 cmol (+)/kg) and then T_8 (-0.045 cmol (+)/kg). In the second year (2017-2018), there was an increasing trend of K being noticed from all the treatments but not in T_0. The higher increased value of K (+0.013 cmol (+)/kg) was obtained from T_4, whereas the lower one was recorded from T_0 (-0.002 cmol (+)/kg). At the end of the study (2018-2019), exchangeable potassium ranged from -0.008 to +0.015 (cmol (+)/kg), where the upper value (+0.015 cmol (+)/kg) was demonstrated by the treatment T_4 and the lower one was observed in T_0 (-0.008 cmol (+)/kg).

Table 12: Changes of soil exchangeable potassium (cmol (+)/kg) as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	0.150	0.088	-0.063*	0.088	0.085	-0.002 ns	0.085	0.078	-0.008 ns
T_1	0.150	0.110	-0.040*	0.110	0.118	+0.007 ns	0.118	0.122	+0.004 ns
T_2	0.150	0.118	-0.033*	0.118	0.123	+0.005 ns	0.123	0.130	+0.008 ns
T_3	0.150	0.123	-0.028*	0.123	0.133	+0.010 ns	0.133	0.145	+0.012*
T_4	0.150	0.133	-0.018*	0.133	0.145	+0.013*	0.145	0.160	+0.015*
T_5	0.150	0.128	-0.023*	0.128	0.135	+0.008 ns	0.135	0.143	+0.008 ns
T_6	0.150	0.114	-0.036*	0.114	0.122	+0.008 ns	0.122	0.130	+0.009 ns
T_7	0.150	0.125	-0.025*	0.125	0.130	+0.005 ns	0.130	0.136	+0.006 ns
T_8	0.150	0.105	-0.045*	0.105	0.110	+0.005 ns	0.110	0.120	+0.010*
LSD (0.05)		0.007			0.010			0.009	
CV (%)		3.300			5.000			4.200	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.2.5 Available phosphorus

The statistical analysis indicated mostly significant differences among the various soil amendments on the available phosphorus in 2016-2017 (Table 13). Available phosphorus was found decreasing in the first year of the experiment where the treatment T_0 led to the maximum deviation (-13.35 µg/g) followed by T_8 (-11.18 µg/g). Compared with the final readings between 2016-2017 and 2017-2018, a little enhancement was recorded by all the treatments except in T_0. The treatment T_3 led to the highest enhancement of available phosphorus (+5.42 µg/g), while the opposite result with lessen value (-0.70 µg/g) was observed from $T_{0.}$ The year 2018-2019, the advancement trend of phosphorus remains unchanged and the value +4.05 µg/g was led to a higher increase but -1.07 µg/g was indicated the reduction by T_3 and $T_{0,}$ respectively.

Table 13: Changes of soil available phosphorus (µg/g) as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	26.30	12.96	-13.35*	12.96	12.26	-0.70 ^{ns}	12.26	11.19	-1.07 ^{ns}
T_1	26.30	23.49	-2.82*	23.49	24.42	+0.93 ^{ns}	24.42	25.85	+1.44 ^{ns}
T_2	26.30	25.65	-0.66 ^{ns}	25.65	29.36	+3.72*	29.36	31.54	+2.18*
T_3	26.30	26.09	-0.22 ^{ns}	26.09	31.50	+5.42*	31.50	35.55	+4.05*
T_4	26.30	25.22	-1.09*	25.22	27.33	+2.11*	27.33	29.34	+2.02*
T_5	26.30	19.23	-7.07*	19.23	20.52	+1.29 ^{ns}	20.52	21.57	+1.05 ^{ns}
T_6	26.30	21.41	-4.89*	21.41	22.96	+1.55*	22.96	24.14	+1.18 ^{ns}
T_7	26.30	16.79	-9.51*	16.79	17.70	+0.91 ^{ns}	17.70	18.60	+0.90 ^{ns}
T_8	26.30	15.13	-11.18*	15.13	16.53	+1.40 ^{ns}	16.53	17.50	+0.98 ^{ns}
LSD (0.05)		1.00			1.43			1.87	
CV (%)		2.60			4.00			4.80	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.2.6 Available sulphur

Available sulphur (S) content of soil mostly showed an increasing trend due to addition of different soil amendments after the completion of the first year experiment (Table 14). The large significant gain (+4.51 µg/g) of available sulphur occurred in T_3. On the other hand, a small decrease (-0.05 µg/g) on this parameter was recorded under T_8 over the initial value. A little gain was demonstrated by all the treatments except control (T_0) at the second year of the study. However, the utmost enhance (+1.32 µg/g) and decline (-0.92 µg/g) were reported by the treatments T_4 and T_0 correspondingly. The treatments had the similar tendency in the final year that was shown in the previous year on this element. But there the higher and the lower value was denoted as +1.45 and -0.97 µg/g under the treatment T_3 and T_0, respectively.

Table 14: Changes of soil available sulphur (µg/g) as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	12.50	11.56	-0.94 ^{ns}	11.56	10.65	-0.92 ^{ns}	10.65	9.68	-0.97 ^{ns}
T_1	12.50	14.96	+2.46*	14.96	15.73	+0.78 ^{ns}	15.73	16.32	+0.59 ^{ns}
T_2	12.50	16.17	+3.67*	16.17	17.42	+1.25 ^{ns}	17.42	18.53	+1.11 ^{ns}
T_3	12.50	17.01	+4.51*	17.01	18.20	+1.20 ^{ns}	18.20	19.65	+1.45 ^{ns}
T_4	12.50	15.39	+2.89*	15.39	16.71	+1.32 ^{ns}	16.71	18.02	+1.31 ^{ns}
T_5	12.50	13.79	+1.29*	13.79	14.83	+1.05 ^{ns}	14.83	15.78	+0.95 ^{ns}
T_6	12.50	14.21	+1.71*	14.21	15.36	+1.15 ^{ns}	15.36	16.21	+0.86 ^{ns}
T_7	12.50	13.39	+0.89 ^{ns}	13.39	14.42	+1.03 ^{ns}	14.42	15.35	+0.93 ^{ns}
T_8	12.50	12.45	-0.05 ^{ns}	12.45	13.05	+0.60 ^{ns}	13.05	13.83	+0.78 ^{ns}
LSD (0.05)		1.06			1. 46			1.58	
CV (%)		4.80			6.00			6.10	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.2.7 Available zinc

Data presented in the table (Table 15) revealed that the available zinc was significantly influenced by different soil amendments except T_3 and T_4 in 2016-2017. The maximum significant depletion of zinc (-0.15 µg/g) was observed in T_0 but a minor decline was noticed in T_4 (-0.02 µg/g). Positive balances of available zinc over initial were recorded by the amendments but not in T_0 and T_8 in 2017-2018. The treatment T_4 (+0.05 µg/g) and T_3 (+0.05 µg/g) were presented with a greater increase of zinc, however, only T_0 (-0.03 µg/g) had the decrease effect. Incase of 2018-2019, treatment T_4 followed by T_3 showed the maximum significant gain in total zinc with the values of +0.06 and +0.05 µg/g, respectively (Table 15). Furthermore, total available zinc was slightly reduced under the treatment T_0 (-0.04 µg/g) and T_8 (-0.02 µg/g).

Table 15: Changes of soil available zinc (µg/g) as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	0.75	0.60	-0.15*	0.60	0.56	-0.03 ^{ns}	0.56	0.54	-0.04 ^{ns}
T_1	0.75	0.63	-0.13*	0.63	0.65	+0.03 ^{ns}	0.65	0.69	+0.04 ^{ns}
T_2	0.75	0.70	-0.05 ^{ns}	0.70	0.74	+0.04 ^{ns}	0.74	0.78	+0.04 ^{ns}
T_3	0.75	0.73	-0.03 ^{ns}	0.73	0.77	+0.05 ^{ns}	0.77	0.82	+0.05 ^{ns}
T_4	0.75	0.74	-0.02*	0.74	0.79	+0.05 ^{ns}	0.79	0.84	+0.06 ^{ns}
T_5	0.75	0.68	-0.07*	0.68	0.72	+0.04 ^{ns}	0.72	0.75	+0.03 ^{ns}
T_6	0.75	0.64	-0.12*	0.64	0.66	+0.02 ^{ns}	0.66	0.68	+0.02 ^{ns}
T_7	0.75	0.66	-0.10*	0.66	0.67	+0.02 ^{ns}	0.67	0.70	+0.03 ^{ns}
T_8	0.75	0.62	-0.13*	0.62	0.61	-0.01 ^{ns}	0.61	0.59	-0.02 ^{ns}
LSD (0.05)		0.05			0.08			0.12	
CV (%)		4.00			7.20			10.00	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.2.8 Electrical conductivity

The statistical analysis indicated differences among the various soil amendments on electrical conductivity in 2016-2017 (Table 16). Electrical conductivity (EC) was decreased under the control treatment (T_0) and all other amendments were increased the EC. Here T_4 had the maximum (+10.50 µs/cm) EC than the other treatments. In the year 2017-2018, positive EC was recorded by most of the treatments, but not in T_0. Here the treatment T_4 led to the highest enhancement of EC (+12.50 µs/cm), while the decreased EC (-6.50 µs/cm) was observed in $T_{0.}$ Except $T_{0,}$ there was also found positive deviation of EC over initial by addition of other treatments in 2018-2019. Nevertheless, the advancement of EC +13.00 µs/cm led to the higher increase which was shown by T_4 but -7.00 µs/cm was indicate by T_0, respectively.

Table 16: Changes of soil electrical conductivity (µs/cm) as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	145.00	140.00	-5.00*	140.00	133.50	-6.50*	133.50	126.50	-7.00*
T_1	145.00	147.00	+2.00^{ns}	147.00	150.00	+3.00^{ns}	150.00	153.50	+3.50^{ns}
T_2	145.00	150.50	+5.50*	150.50	160.00	+9.50*	160.00	167.50	+7.50*
T_3	145.00	152.50	+7.50*	152.50	164.00	+11.50*	164.00	175.00	+11.00*
T_4	145.00	155.50	+10.50*	155.50	168.00	+12.50*	168.00	181.00	+13.00*
T_5	145.00	147.00	+2.00^{ns}	147.00	149.50	+2.50^{ns}	149.50	152.50	+3.00^{ns}
T_6	145.00	149.00	+4.00*	149.00	154.00	+5.00^{ns}	154.00	160.50	+6.50*
T_7	145.00	146.50	+1.50^{ns}	146.50	147.50	+1.00^{ns}	147.50	149.50	+2.00^{ns}
T_8	145.00	147.50	+2.50^{ns}	147.50	151.50	+4.00^{ns}	151.50	156.50	+5.00^{ns}
LSD (0.05)		3.58			5.58			5.85	
CV (%)		1.50			2.20			2.30	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.1.2.9 Carbon nitrogen ratio

There was a significant influence of various soil amendments on carbon nitrogen ratio (C:N) in the year 2016-2017 (Table 17). Here the C:N was found to be greater (+4.15) under the treatment T_0, while the plots under treatment T_5 provided the lower C:N (+0.12) of soil. As the consecutive year 2017-2018, C:N was declined insignificantly by the application of different soil amendments without T_0 and T_8. The treatment T_4 was demonstrated the higher decrease of C:N (-0.69), whereas the increase of C:N was found from T_0 (+4.42) and T_8 (+1.31). At the end year of the study, the result revealed that the C:N of soil was also decreased for all the applied treatments except T_0 and T_8. The most decrease of C:N was recorded in T_4 (-0.60) but a major positive value was found in T_8 (+4.88).

Table 17: Changes of soil carbon nitrogen ratio (C:N) as influenced by different soil amendments for three consecutive years of wheat production.

Treatment	2016-2017			2017-2018			2018-2019		
	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change
T_0	10.00	14.15	+4.15*	14.15	18.64	+4.42*	18.64	22.91	+4.22*
T_1	10.00	13.80	+3.80*	13.80	13.52	-0.28 ^{ns}	13.52	13.70	-0.14 ^{ns}
T_2	10.00	12.64	+2.64*	12.64	12.19	-0.44 ^{ns}	12.19	11.87	-0.32 ^{ns}
T_3	10.00	11.51	+1.51*	11.51	10.88	-0.63 ^{ns}	10.88	10.52	-0.35 ^{ns}
T_4	10.00	10.47	+0.47*	10.47	8.75	-0.69 ^{ns}	8.75	8.16	-0.60 ^{ns}
T_5	10.00	10.12	+0.12*	10.12	9.44	-0.68 ^{ns}	9.44	8.89	-0.55 ^{ns}
T_6	10.00	12.72	+2.72*	12.72	12.57	-0.15 ^{ns}	12.57	12.48	-0.45 ^{ns}
T_7	10.00	10.58	+0.58*	10.58	10.05	-0.52 ^{ns}	10.05	9.64	-0.41 ^{ns}
T_8	10.00	12.49	+2.49*	12.49	13.80	+1.31 ^{ns}	13.80	18.69	+4.88*
LSD (0.05)		0.91			2.22			2.20	
CV (%)		5.00			11.20			10.70	

T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, NS = Non-significant difference between initial and final values, * = Significant ($p \leq 0.05$), LSD = Least significant difference, CV = Co-efficient of variation.

4.2 Wheat

4.2.1 Seedling infection

After 14 days of sowing the seedling infection was recorded in the three consecutive cropping years (Table 18). The treatment used for the study showed significant results in reducing seedling infection in the field during the study periods 2016-2017, 2017-2018 and 2018-2019. Among the selected three varieties of wheat, the variety BARI wheat-28 (V_1) showed the higher infection (1.24%), while the variety BARI wheat- 30 (V_3) exhibited minimum seedling infection (0.92%).

Regarding treatment effect, the lower rate of seedling infection (0.32%) was found after application *Trichoderma harzianum* (T_5) in comparison with the maximum infection from T_0 (2.32%) in 2018-2019. All the treatments in the experimental period presented significant differences among each other. But T_1 (Rice straw + vermicompost + green manure) and T_8 (Chemical fertilizer) was statistically identical. Reduction of seedling infection at 14 DAS under different soil amendments showed more or less the following order as $T_5>T_7>T_4>T_3>T_2>T_6>T_1>T_8>T_0$ during the whole research period (Table 19).

Though all the amendments in combination with variety showed significant performance in reducing seedling infection at 14 DAS, but T_5 with each variety was presented the minimum infection in the three consecutive years. The lowest (0.25%) and the highest (2.69%) infection of seedling were found in 2018-2019 from V_3T_5 and V_1T_0, respectively. Along with significant difference, parallel tendency were noticed regarding lower infection rate by V_2T_5 (0.33%) and V_1T_5 (0.38%) but higher infection values were recorded from V_2T_0 (2.40%) and V_3T_0 (1.88%) in same year of the study. Similar results were also noticed from the aforesaid combination during 2016-2017 and 2017-2018 (Table 20).

4.2.2 Seedling blight

The frequency of seedling blight at 21 DAS was recorded and found to be significantly different for all varieties. In the experiment, the higher seedling blight was found in V_1 and the lower was in V_3 throughout the study time (Table 18). Hence, the highest percentage survivability of seedling was obtained from V_3 (1.73%) in 2017-2018 and the lowest from V_1 (2.41%) in 2018-2019.

Under this study, recorded results showed that there was a significant variation among the treatments. The highest inhibition effect against seedling blight (0.87%) was observed by treatment T_5 and the lowest (4.74%) from control ($T_{0)}$ during 2018-2019. Next to treatment $T_{5,}$ the treatment T_7 also showed remarkable effect in reducing seedling blight (1.07%) which was statistically identical (1.09%) with T_4 (Table 19).

The interaction effect of treatments and variety clearly demonstrated significant influence on seedling blight at 21 DAS. All the varieties presented the minimum blight incidence in combination with T_5, while the maximum blight was found from combination with T_0 in the whole time of study (Table 20). The results indicated that among the treatment, V_3T_5 combination gave the comparatively lower seedling blight incidence (0.73%) in 2018-2019. On the other hand, V_1T_0 showed the higher seedling blight incidence (5.44%) in 2018-2019.

4.2.3 Leaf chlorophyll content

Leaf chlorophyll content of wheat was affected significantly due to varietal influences in the three years of this experiment. From the responses of individual variety, provided the following order $V_3>V_2>V_1$ in respect of chlorophyll content over the whole study period (Table 18). Among three varieties, V_3 produced the sharp increase of chlorophyll content and it was recorded maximum (45.87 SPAD) during 2018-2019 which exhibited a statistically similar result (45.42 SPAD) with V_1 at the same year.

A significant difference was observed from various soil amendments for the chlorophyll content of wheat leaf at 70 DAS. The biggest value of chlorophyll content (51.48 SPAD) was recorded from chemical fertilizer (T_8) and which was followed by T_4 (48.37 SPAD) and T_5 (48.08). In this regard, the smallest value (40.33 SPAD) was noticed from T_0 during the season 2018-2019. Due to soil amendment with chemical fertilizer (T_8) provided more chlorophyll content and the trend was maintained from beginning to the end of the study (Table 19).

Diverse soil amendments in combination with selected varieties attributed significant effect in leaf chlorophyll content of wheat. Among all combinations of treatments and variety, V_3T_8 presented higher value (52.52 SPAD), but V_2T_0 had the poorest value (38.40 SPAD) of chlorophyll content during 2018-2019. Indication of chlorophyll content as like above were noticed during the year 2016-2017 and 2017-2018, respectively (Table 20).

Table 18: Effect of variety on seedling infection, seedling blight and leaf chlorophyll content of wheat.

Variety	Seedling infection (%)			Seedling blight (%)			Leaf chlorophyll content (SPAD)		
	14 Days after sowing			21 Days after sowing			70 Days after sowing		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	1.26 ± 0.13a	1.22 ± 0.12a	1.28 ± 0.14a	2.24 ± 0.17a	2.09 ± 0.17a	2.41 ± 0.26a	42.29 ± 0.65b	43.61 ± 0.69b	45.42 ± 0.73a
V_2	1.15 ± 0.11b	1.12 ± 0.11b	1.10 ± 0.12b	2.04 ± 0.15b	1.92 ± 0.15b	1.98 ± 0.21b	41.31 ± 0.59c	42.87 ± 0.75c	44.13 ± 0.81b
V_3	1.02 ± 0.09c	0.94 ± 0.09c	0.97 ± 0.10c	1.83 ± 0.13c	1.73 ± 0.13c	1.84 ± 0.20c	43.03 ± 0.75a	44.65 ± 0.79a	45.87 ± 0.73a
LS	**	**	**	**	**	**	**	**	*
CV (%)	5.42	6.89	4.38	5.59	6.16	4.30	0.80	0.79	5.09

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, DAS = Days after sowing, SPAD = The soil plant analysis development, LS = Level of significance, ** = 1% Level of significance, * = 5% Level of significance, CV = Co-efficient of variation.

Table 19: Effect of organic and probiotic soil amendments on seedling infection, seedling blight and leaf chlorophyll content of wheat.

Treatment	Seedling infection (%)			Seedling blight (%)			Leaf chlorophyll content (SPAD)		
	14 Days after sowing			21 Days after sowing			70 Days after sowing		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
T_0	2.14 ± 0.12a	1.99 ± 0.09a	2.32 ± 0.13a	3.52 ± 0.16a	3.30 ± 0.16a	4.74 ± 0.20a	38.26 ± 0.85h	38.82 ± 0.90g	40.33 ± 0.79d
T_1	1.49 ± 0.03b	1.47 ± 0.05b	1.46 ± 0.09b	2.53 ± 0.08b	2.41 ± 0.08b	2.48 ± 0.19c	40.18 ± 0.90g	41.62 ± 0.86f	42.77 ± 0.87c
T_2	1.34 ± 0.04d	1.24 ± 0.05c	1.20 ± 0.04c	2.17 ± 0.06c	2.04 ± 0.04d	2.11 ± 0.08d	41.39 ± 0.87f	43.56 ± 1.05de	42.96 ± 0.76c
T_3	0.93 ± 0.04e	0.87 ± 0.03d	0.92 ± 0.05d	1.77 ± 0.05d	1.71 ± 0.05e	1.61 ± 0.04e	42.45 ± 0.85d	43.85 ± 1.04d	44.09 ± 0.85c
T_4	0.59 ± 0.02f	0.58 ± 0.02e	0.55 ± 0.01e	1.24 ± 0.05e	1.19 ± 0.06f	1.09 ± 0.05f	44.59 ± 0.81b	46.63 ± 0.89b	48.37 ± 0.80b
T_5	0.35 ± 0.02g	0.34 ± 0.02g	0.32 ± 0.02g	0.93 ± 0.06f	0.87 ± 0.04g	0.87 ± 0.05g	43.03 ± 0.85c	44.73 ± 0.91c	48.08 ± 0.61b
T_6	1.43 ± 0.02c	1.44 ± 0.06b	1.42 ± 0.08b	2.44 ± 0.07b	2.33 ± 0.08bc	2.16 ± 0.11d	41.08 ± 0.89f	41.80 ± 0.92f	43.06 ± 0.63c
T_7	0.57 ± 0.02f	0.46 ± 0.02f	0.45 ± 0.03f	1.29 ± 0.04e	1.11 ± 0.03f	1.07 ± 0.06f	41.78 ± 0.92e	43.45 ± 0.95e	45.11 ± 0.71c
T_8	1.48 ± 0.10c	1.47 ± 0.08b	1.42 ± 0.04b	2.44 ± 0.09b	2.26 ± 0.04c	2.57 ± 0.11b	47.14 ± 0.97a	48.92 ± 1.08a	51.48 ± 0.70a
LS	**	**	**	**	**	**	**	**	**
CV (%)	5.42	6.89	4.38	5.59	6.16	4.30	0.80	0.79	5.09

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

Table 20: Interaction effect of variety and soil amendments on seedling infection, seedling blight and leaf chlorophyll content of wheat.

Variety & Treatment		Seedling infection (%)			Seedling blight (%)			Leaf chlorophyll content (SPAD)		
		14 Days after sowing			21 Days after sowing			70 Days after sowing		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	T_0	2.52 ± 0.08a	2.26 ± 0.07a	2.69 ± 0.090a	4.01 ± 0.18a	3.81 ± 0.16a	5.44 ± 0.18a	37.79 ± 1.86l	39.22 ± 1.36n	40.90 ± 1.39
	T_1	1.55 ± 0.04e	1.58 ± 0.07de	1.78 ± 0.05d	2.74 ± 0.14d	2.60 ± 0.18cd	3.21 ± 0.15c	40.85 ± 1.77hi	41.75 ± 1.47k	43.05 ± 1.74
	T_2	1.48 ± 0.04ef	1.37 ± 0.04f	1.28 ± 0.06hi	2.32 ± 0.10gh	2.05 ± 0.08hi	2.39 ± 0.07f	41.82 ± 1.69g	44.85 ± 1.94f	43.02 ± 1.38
	T_3	0.98 ± 0.02k	0.95 ± 0.03i	1.10 ± 0.05j	1.86 ± 0.07jk	1.79 ± 0.10jk	1.62 ± 0.08j	42.22 ± 1.74fg	42.57 ± 1.76ij	45.14 ± 1.74
	T_4	0.61 ± 0.03m	0.63 ± 0.02kl	0.55 ± 0.03l	1.38 ± 0.06m	1.39 ± 0.06l	1.25 ± 0.06k	44.68 ± 1.43d	46.71 ± 1.45d	47.33 ± 1.52
	T_5	0.40 ± 0.02op	0.39 ± 0.02mn	0.38 ± 0.02m	1.15 ± 0.03no	1.01 ± 0.04mn	1.03 ± 0.05l	43.31 ± 1.42e	43.12 ± 1.54hi	48.90 ± 1.04
	T_6	1.38 ± 0.05fgh	1.55 ± 0.07e	1.72 ± 0.07d	2.57 ± 0.06de	2.60 ± 0.08cd	2.57 ± 0.05e	41.12 ± 1.54h	42.76 ± 1.89hi	43.70 ± 1.14
	T_7	0.62 ± 0.02m	0.523 ± 0.02kl	0.53 ± 0.02l	1.36 ± 0.07m	1.14 ± 0.02m	1.26 ± 0.05k	42.09 ± 1.61fg	42.96 ± 1.86hi	45.37 ± 1.40
	T_8	1.84 ± 0.08c	1.72 ± 0.07c	1.54 ± 0.02e	2.74 ± 0.09d	2.38 ± 0.05ef	2.92 ± 0.08d	46.73 ± 1.49b	48.53 ± 1.94b	51.38 ± 1.45
V_2	T_0	2.16 ± 0.09b	2.00 ± 0.10b	2.40 ± 0.06b	3.54 ± 0.10b	3.31 ± 0.09b	4.43 ± 0.12b	38.11 ± 1.27l	37.22 ± 1.50o	38.40 ± 0.92
	T_1	1.52 ± 0.04e	1.51 ± 0.05e	1.40 ± 0.04fg	2.53 ± 0.06ef	2.42 ± 0.12de	2.16 ± 0.10g	39.32 ± 1.82k	41.00 ± 1.55l	42.08 ± 1.70
	T_2	1.30 ± 0.05hij	1.26 ± 0.06fg	1.22 ± 0.03i	2.14 ± 0.02hi	2.14 ± 0.02ghi	1.98 ± 0.05hi	40.55 ± 1.52hij	42.03 ± 1.94jk	41.55 ± 1.38
	T_3	1.02 ± 0.05k	0.90 ± 0.04i	0.85 ± 0.03k	1.82 ± 0.08kl	1.75 ± 0.08jk	1.68 ± 0.06j	41.78 ± 1.59g	43.21 ± 1.92h	42.27 ± 0.92
	T_4	0.61 ± 0.01mn	0.58 ± 0.02kl	0.56 ± 0.02l	1.26 ± 0.06mno	1.16 ± 0.02m	1.04 ± 0.05l	43.35 ± 1.22e	45.67 ± 1.71e	48.57 ± 1.62
	T_5	0.34 ± 0.01pq	0.34 ± 0.02mn	0.33 ± 0.01mn	0.84 ± 0.03p	0.84 ± 0.02no	0.83 ± 0.03mn	42.50 ± 1.84f	44.87 ± 1.63f	47.62 ± 1.36
	T_6	1.46 ± 0.04efg	1.54 ± 0.04e	1.20 ± 0.05i	2.51 ± 0.10efg	2.29 ± 0.08efg	2.05 ± 0.08gh	40.07 ± 1.51j	41.00 ± 1.67l	41.97 ± 1.08
	T_7	0.60 ± 0.02mn	0.46 ± 0.01lm	0.47 ± 0.02l	1.33 ± 0.06mn	1.15 ± 0.04m	1.03 ± 0.04l	40.95 ± 1.89hi	43.07 ± 1.87hi	44.22 ± 1.20
	T_8	1.35 ± 0.06ghi	1.56 ± 0.06e	1.45 ± 0.04f	2.35 ± 0.07fgh	2.25 ± 0.05e-h	2.61 ± 0.07e	45.17 ± 1.45d	47.79 ± 1.91c	50.52 ± 0.93

Contd...

Variety & Treatment		Seedling infection (%)			Seedling blight (%)			Leaf chlorophyll content (SPAD)		
		14 Days after sowing			21 Days after sowing			70 Days after sowing		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_3	T_0	1.74 ± 0.04d	1.70 ± 0.04cd	1.88 ± 0.09c	3.00 ± 0.07c	2.79 ± 0.12c	4.36 ± 0.21b	38.89 ± 1.80k	40.02 ± 1.85m	41.70 ± 1.35
	T_1	1.41 ± 0.03fgh	1.31 ± 0.02fg	1.21 ± 0.05i	2.33 ± 0.10gh	2.19 ± 0.06fgh	2.07 ± 0.05gh	40.36 ± 1.64ij	42.11 ± 1.98jk	43.17 ± 1.69
	T_2	1.24 ± 0.05j	1.09 ± 0.04h	1.11 ± 0.05j	2.03 ± 0.07ij	1.93 ± 0.05ij	1.95 ± 0.09hi	41.80 ± 1.81g	43.79 ± 1.90g	44.32 ± 1.07
	T_3	0.79 ± 0.02l	0.76 ± 0.01j	0.82 ± 0.02k	1.64 ± 0.09l	1.59 ± 0.05k	1.54 ± 0.07j	43.36 ± 1.55e	45.76 ± 1.80e	44.88 ± 1.47
	T_4	0.54 ± 0.03mn	0.54 ± 0.01kl	0.53 ± 0.02l	1.08 ± 0.04o	1.02 ± 0.04mn	0.97 ± 0.04lm	45.73 ± 1.72c	47.51 ± 1.92c	49.22 ± 1.36
	T_5	0.30 ± 0.02q	0.28 ± 0.01n	0.25 ± 0.02n	0.78 ± 0.02p	0.76 ± 0.02o	0.73 ± 0.03n	43.28 ± 1.75e	46.21 ± 1.56de	47.73 ± 1.02
	T_6	1.45 ± 0.04efg	1.22 ± 0.04gh	1.36 ± 0.06gh	2.23 ± 0.08hi	2.10 ± 0.03ghi	1.86 ± 0.06i	42.06 ± 1.94fg	41.65 ± 1.71k	43.52 ± 1.21
	T_7	0.50 ± 0.01no	0.38 ± 0.01mn	0.35 ± 0.02m	1.19 ± 0.06mno	1.03 ± 0.05mn	0.92 ± 0.05lm	42.30 ± 1.87fg	44.31 ± 1.79fg	45.75 ± 1.40
	T_8	1.25 ± 0.05ij	1.20 ± 0.03gh	1.27 ± 0.04i	2.23 ± 0.08hi	2.16 ± 0.04gh	2.18 ± 0.05g	49.51 ± 1.56a	50.45 ± 2.19a	52.52 ± 1.38
	LS	**	**	**	**	**	**	**	**	NS
	CV (%)	5.42	6.89	4.38	5.59	6.16	4.30	0.80	0.79	5.09

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

4.3 Growth attributes

4.3.1 Total dry matter

Generally, with the advancement of time the total dry matter (TDM) accumulation of wheat plant was positively increased in all varieties. TDM varied significantly due to various varietal influences at 25, 40, 55, 70 and 85 DAS during the experimental period (Fig. 3, 4 and 5). Results indicated that TDM was higher in V_3 followed by V_1, but it was lower in V_2 at all dates of sampling. At 85 DAS, the maximum TDM accumulation (722.34 g/m^2) was recorded from V_3 in 2018-2019 and the minimum from V_2 (625.74 g/m^2) in 2016-2017.

From the evaluation of different soil amendments, it has been found significant variation among the treatments at almost all DAS. Most of the treatments showed approximately similar patterns of TDM accumulation. However, the highest TDM was produced in T_8 followed in descending order by T_4, T_5, T_7, T_3, T_2, T_6 and T_1, while the lowest was found in T_0 at all sampling dates round the three years study (Fig. 6, 7 and 8). At 25 DAS, the treatment T_8 presented the uppermost value (34.84 g/m^2) for TDM accumulation, while T_0 gave the lowest (17.03 g/m^2) one in the 2018-2019 cropping season. Thus, considering the TDM production at 40, 55, 70 and 85 DAS the results revealed that the maximum and the minimum accumulation exhibited by T_8 (118.01, 242.53, 561.61, 798.15 g/m^2) and T_0 (45.92, 124.08, 329.92, 532.33 g/m^2), respectively from the sequential year of the study. At the peak (85 DAS) of TDM accumulation, the most statistical identity was found between T_8 (767.14 g/m^2) and T_4 (750.91 g/m^2) and similar trend was also found between T_7 (712.32 g/m^2) and T_3 (706.39 g/m^2) in 2018-2019.

In 2016-2017, TDM accumulation significantly influenced at 25, 40 and 55 DAS by the interaction of variety and different organic soil amendment treatments. Here the great and less values of TDM were recorded on the aforesaid different DAS as V_3T_8 (30.34, 96.97, 222.63 g/m^2) and V_2T_0 (15.91, 43.40, 117.18 g/m^2). However, among the combination, V_2T_8 (207.95 g/m^2) reported higher which was statistically at par with V_3T_4 (205.31 g/m^2) at 55 DAS.

Variation of TDM in respect of combination of variety and different organic soil amendments were significantly differed only at 25 and 55 DAS in the year 2017-2018. But at 25 DAS, V_3T_8 provided the maximum value (31.11 g/m^2) and V_2T_0 showed the minimum value (17.11 g/m^2) of TDM content in the plant. In case of 55 DAS, the highest TDM (230.93 g/m^2) was obtained from the treatment combination of V_3T_8 and the lowest (127.47 g/m^2) was observed in V_2T_0. Due to treatment application significant differences of TDM content was notified at 25, 40 and 55 DAS in 2018-2019 and similar trend was observed in 2016-2017. From the above mentioned sampling dates, it was noticed that the production of TDM ranked as followed by the combination V_3T_8 (252.05 g/m^2) >V_1T_8 (242.89 g/m^2) >V_2T_8 (232.65 g/m^2) and V_3T_0 (157.92 g/m^2) >V_1T_0 (145.62 g/m^2) >V_2T_0 (139.22 g/m^2) in 2018-2019, where statistical identity was noticed between V_3T_8 and V_1T_8 (Table 21).

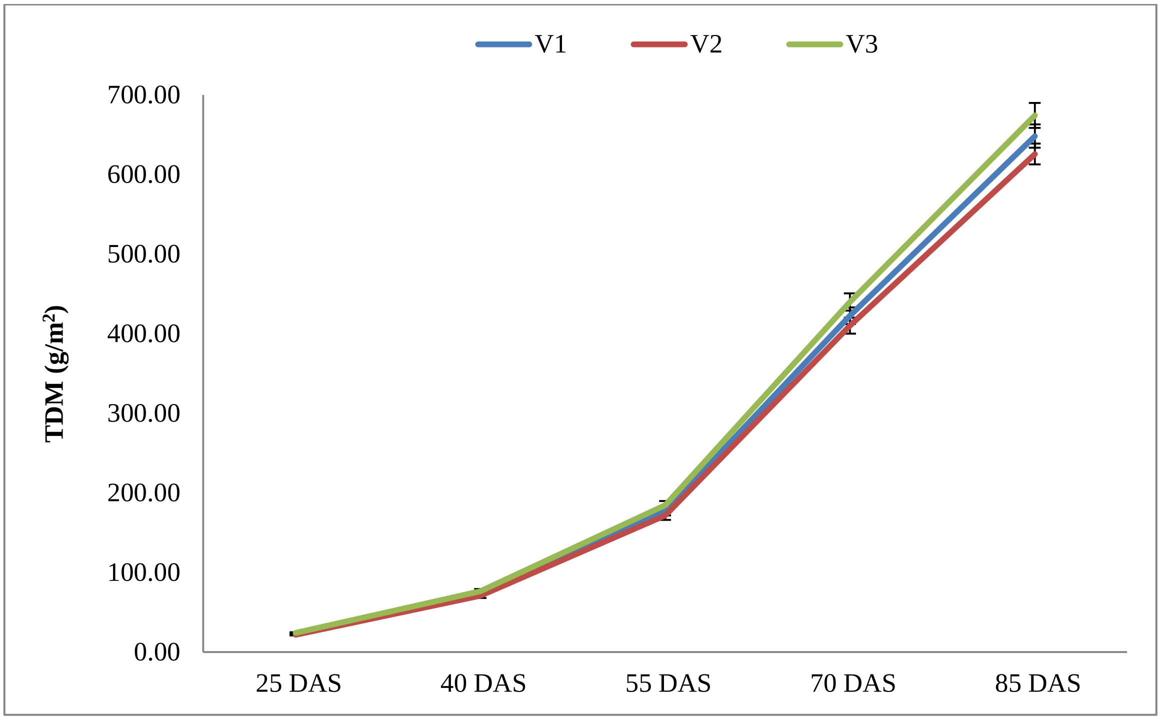


Fig. 3: Effect of variety on total dry matter content of wheat in 2016-2017.

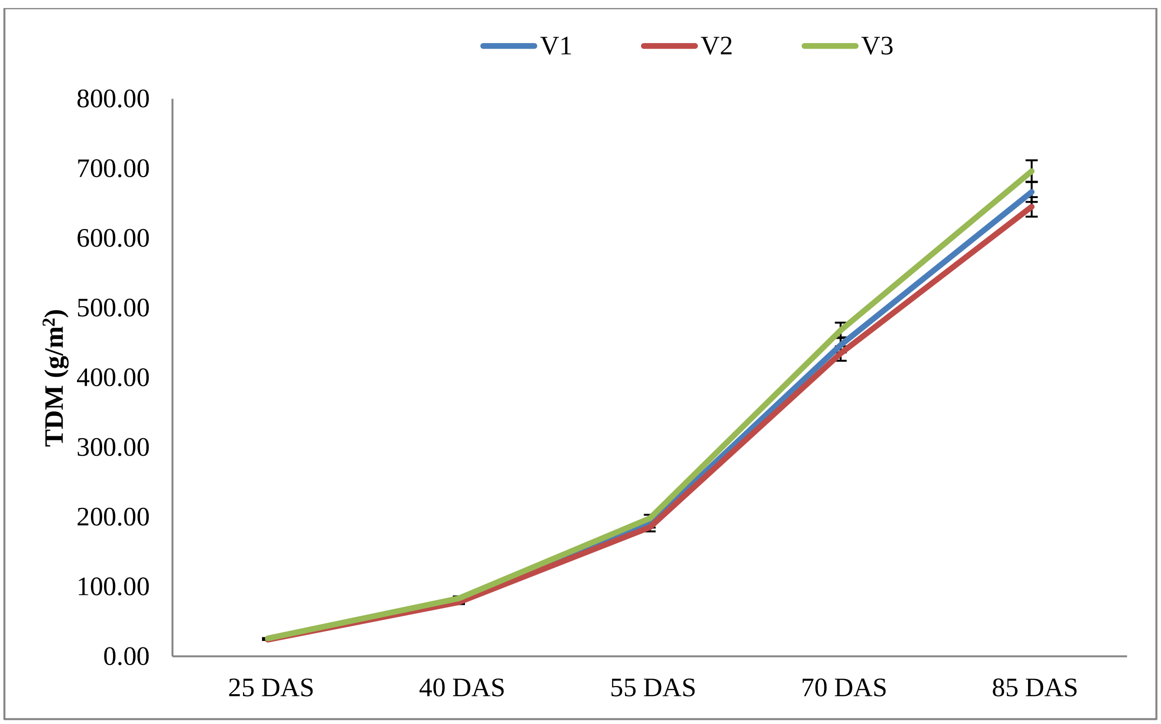


Fig. 4: Effect of variety on total dry matter content of wheat in 2017-2018.

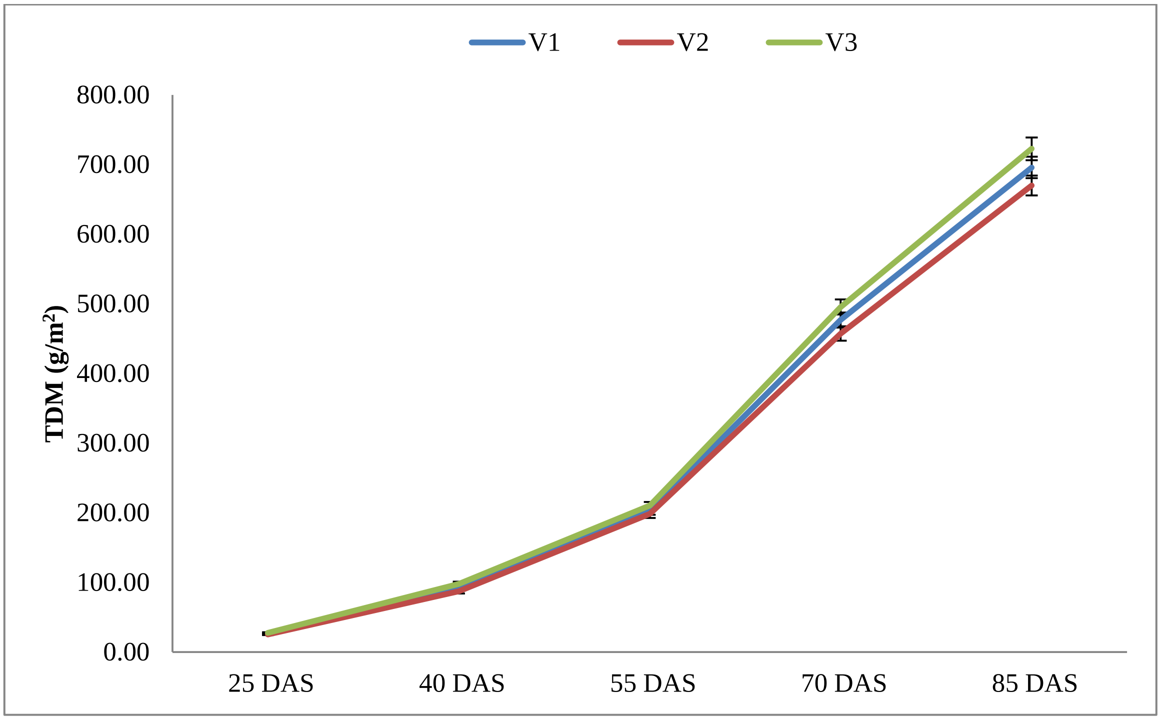


Fig. 5: Effect of variety on total dry matter content of wheat in 2018-2019.

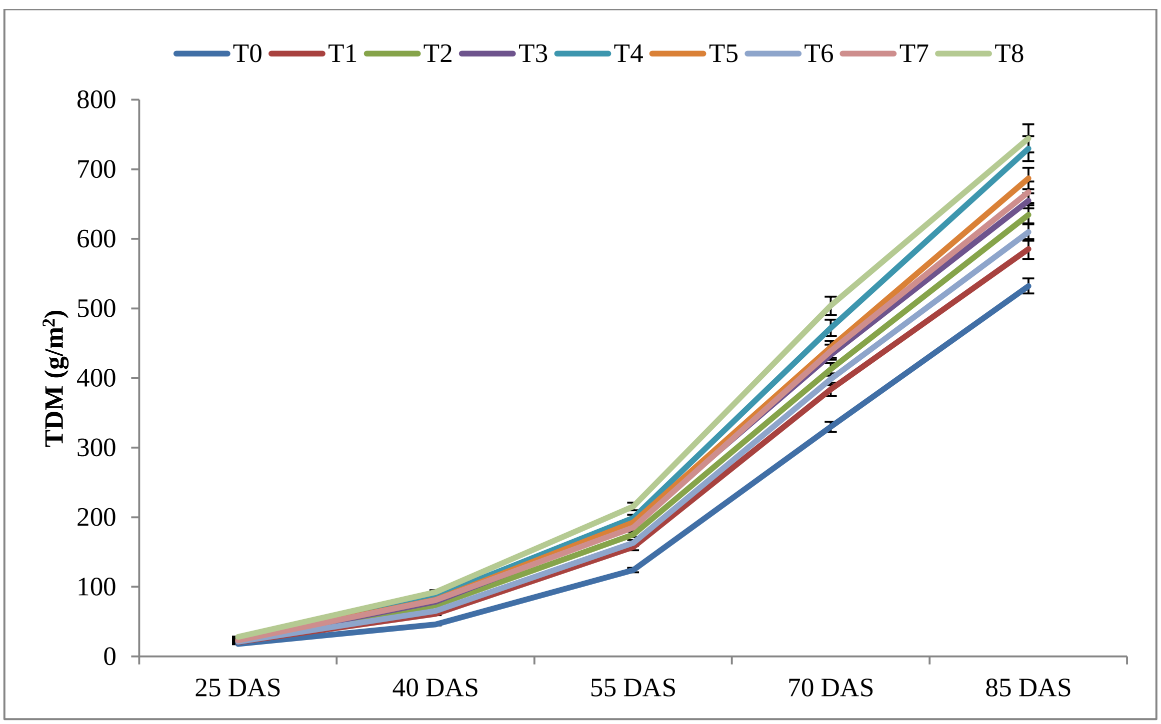


Fig. 6: Effect of organic and probiotic soil amendments on total dry matter content of wheat in 2016-2017.

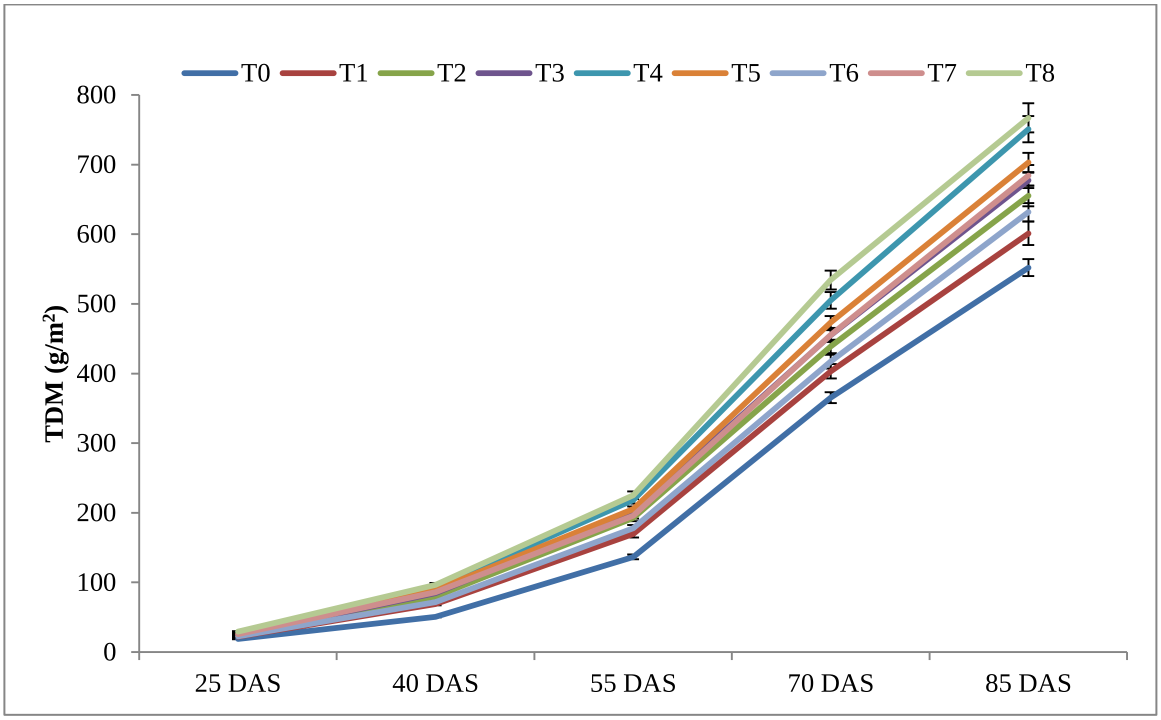


Fig. 7: Effect of organic and probiotic soil amendments on total dry matter content of wheat in 2017-2018.

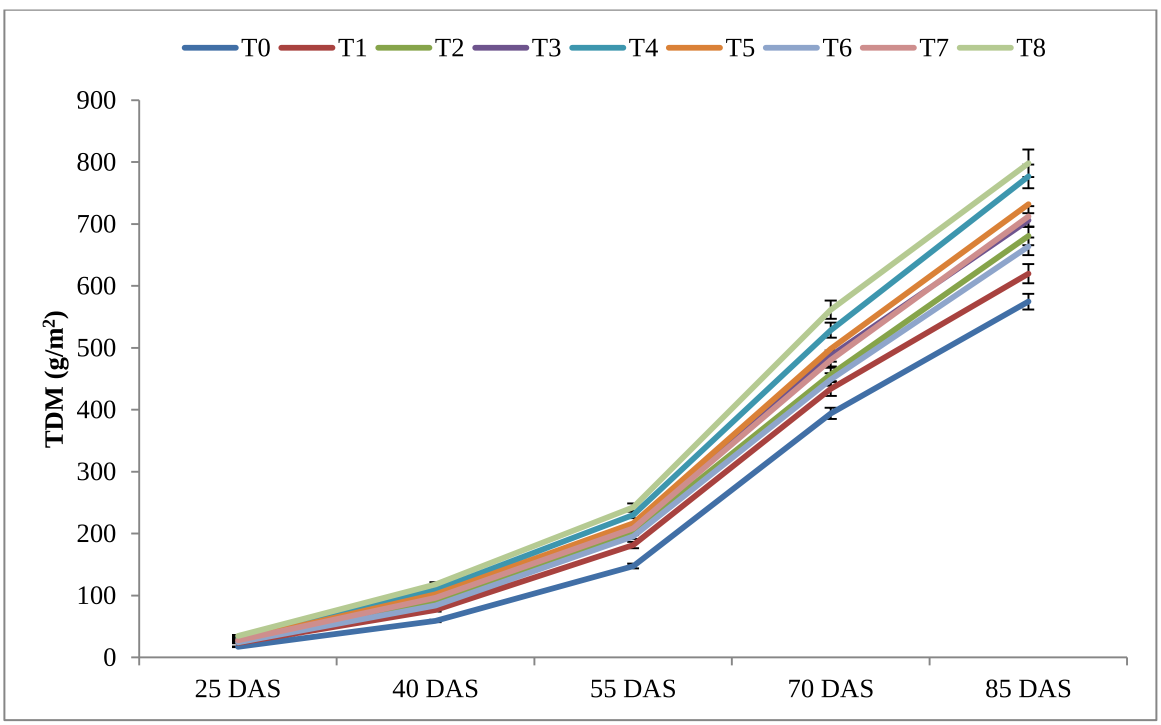


Fig. 8: Effect of organic and probiotic soil amendments on total dry matter content of wheat in 2018-2019.

Table 21: Interaction effects variety and of soil amendments on total dry matter content of wheat (g/m^2).

Variety & Treatment		2016-2017					2017-2018					2018-2019				
		Days after sowing (DAS)														
		25	40	55	70	85	25	40	55	70	85	25	40	55	70	85
V_1	T_0	18.95 ± 0.82n	45.05 ± 1.95n	123.57 ± 5.35r	325.24 ± 14.08	528.50 ± 22.89	20.06 ± 0.87m	50.92 ± 2.21	137.44 ± 5.95o	368.48 ± 15.96	556.70 ± 24.11	16.42 ± 0.71m	60.34 ± 2.613o	145.62 ± 6.31p	400.52 ± 17.34	576.84 ± 24.98
	T_1	20.67l ± 1.01m	61.86 ± 3.04k	156.99 ± 7.70no	386.93 ± 18.99	588.54 ± 28.88	21.80 ± 1.07l	67.93 ± 3.33	167.09 ± 8.20mn	397.28 ± 19.50	600.46 ± 29.47	22.32 ± 1.10k	75.42 ± 3.70m	178.56 ± 8.76n	431.28 ± 19.43	618.66 ± 30.36
	T_2	21.56 ± 0.67ijk	76.75 ± 3.64fg	175.13 ± 8.38m	411.80 ± 18.00	632.97 ± 27.31	23.50 ± 0.78ij	80.65 ± 4.00	190.15 ± 8.96kl	435.25 ± 15.89	652.51 ± 31.90	24.28 ± 0.83ij	85.67 ± 4.234j	200.41 ± 8.68jkl	457.43 ± 20.64	679.21 ± 29.34
	T_3	22.72 ± 0.92gh	78.72 ± 3.18efg	188.57 ± 7.62f-j	428.25 ±17.31	647.41 ± 26.17	25.07 ± 1.01gh	84.11 ± 3.40	201.83 ± 8.16ghi	454.77 ± 18.38	674.34 ± 27.25	26.83 ± 1.08fg	96.57 ± 3.903h	213.86 ± 8.64e-i	484.89 ± 19.60	702.63 ± 28.40
	T_4	25.76 ± 1.19d	86.99 ± 4.02c	198.72 ± 9.18d	469.71 ± 21.70	725.94 ± 33.53	28.71 ± 1.33cd	92.83 ± 4.29	219.34 ± 10.13bcd	503.23 ± 23.24	751.01 ± 34.69	30.75 ± 1.42bc	108.24 ± 4.999de	232.68 ± 10.75cd	530.34 ± 24.50	780.03 ± 36.03
	T_5	23.36 ± 0.67defg	81.42 ± 2.35de	191.18 ± 5.52efgh	447.14 ± 12.91	691.15 ± 19.95	25.87 ± 0.75g	87.49 ± 2.53	202.08 ± 5.83ghi	463.43 ± 13.38	689.32 ± 19.90	27.32 ± 0.79fg	101.57 ± 2.932f	214.43 ± 6.19efgh	492.03 ± 14.20	730.22 ± 21.08
	T_6	21.25 ± 0.80jkl	63.92 ± 2.40jk	162.86 ± 6.11n	398.99 ± 14.97	610.13 ± 22.90	22.53 ± 0.85jkl	71.63 ± 2.69	173.71 ± 6.52m	413.07 ± 15.50	632.02 ± 23.72	23.94 ± 0.90ij	80.64 ± 3.026l	193.32 ± 7.26lm	451.62 ± 16.95	668.16 ± 25.08
	T_7	23.04 ± 0.80fg	82.98 ± 2.88d	182.16 ± 6.31jk	435.42 ±15.08	663.30 ± 22.98	25.27 ± 0.88gh	85.12 ± 2.95	195.32 ± 6.77ijk	449.35 ± 15.57	678.68 ± 23.51	26.73 ± 0.93g	93.85 ± 3.251h	205.72 ± 7.13hijk	473.42 ± 16.40	709.83 ± 24.59
	T_8	27.41 ± 1.35c	92.25 ± 4.53b	216.35 ± 10.62b	499.29 ± 24.50	745.75 ± 36.60	29.35 ± 1.44bc	95.55 ± 4.69	227.34 ± 11.16ab	536.63 ± 26.34	763.57 ± 37.47	36.77 ± 1.81a	117.81 ± 5.782b	242.89 ± 11.92ab	570.00 ± 27.97	797.22 ± 39.12
V_2	T_0	15.91 ± 0.32o	43.40 ± 0.88n	117.18 ± 2.37s	317.52 ± 6.42	516.75 ± 10.44	17.11 ± 0.35n	48.96 ± 0.99	127.47 ± 2.58p	348.74 ± 7.05	526.51 ± 10.64	15.86 ± 0.32m	52.70 ± 1.065p	139.22 ± 2.81p	372.22 ± 7.52	549.49 ± 11.10
	T_1	19.96 ± 0.75m	55.87 ± 2.10l	146.08 ± 5.48p	368.60 ± 13.83	563.78 ± 21.16	22.42 ± 0.84jkl	65.18 ± 2.45	158.46 ± 5.95n	387.37 ± 14.54	565.83 ± 21.23	23.10 ± 0.87jk	70.13 ± 2.632n	171.44 ± 6.43n	413.99 ± 15.54	595.82 ± 22.36
	T_2	20.84 ± 0.51kl	67.61 ± 2.94hi	170.31 ± 7.12m	402.04 ± 18.58	619.33 ± 26.41	22.96 ± 0.62jkl	77.53 ± 3.45	189.65 ± 8.12kl	427.57 ± 18.75	640.11 ± 27.49	24.56 ± 0.70hij	83.30 ± 3.751jkl	197.76 ± 8.54klm	438.59 ± 18.75	665.19 ± 28.79
	T_3	21.68 ± 0.56ij	77.09 ± 2.00fg	183.94 ± 4.78ijk	425.42 ± 11.05	642.39 ± 16.69	24.39 ± 0.63hi	83.32 ± 2.17	195.29 ± 5.08ijk	442.48 ± 11.50	660.82 ± 17.17	26.03 ± 0.68gh	93.37 ± 2.426hi	206.39 ± 5.36g-k	468.65 ± 12.18	692.87 ± 18.00
	T_4	23.77 ± 1.03ef	83.13 ± 3.60d	193.13 ± 8.36defg	450.79 ± 19.52	697.75 ± 30.21	27.84 ± 1.21de	90.52 ± 3.92	211.57 ± 9.16def	485.25 ± 21.01	713.10 ± 30.88	29.20 ± 1.27de	102.70 ± 4.447f	223.05 ± 9.66de	509.60 ± 22.07	740.10 ± 32.05
	T_5	23.07 ± 0.47fg	80.18 ± 1.62de	189.15 ± 3.82fghi	428.28 ± 8.65	652.61 ± 13.19	25.99 ± 0.53g	87.70 ± 1.77	205.11 ± 4.15fgh	469.76 ± 9.49	692.07 ± 13.99	26.97 ± 0.55fg	97.09 ± 1.96gh	216.13 ± 4.37efg	485.46 ± 9.81	709.03 ± 14.33
	T_6	20.64 ± 0.78lm	61.58 ± 2.31k	152.56 ± 5.73o	383.73 ± 14.40	588.58 ± 22.09	22.23 ± 0.83kl	68.06 ± 2.55	168.61 ± 6.33m	396.26 ± 14.87	606.71 ± 22.77	24.11 ± 0.91ij	81.23 ± 3.05kl	188.96 ± 7.09m	425.45 ± 15.97	636.12 ± 23.87

Contd...

Variety & Treatment		2016-2017					2017-2018					2018-2019				
		Days after sowing (DAS)														
		25	40	55	70	85	25	40	55	70	85	25	40	55	70	85
	T_7	22.58	78.58	185.33	431.03	643.13	25.62	84.52	192.24	446.37	669.46	26.55	94.62	209.25	470.87	687.41
		± 0.98gh	± 3.40efg	± 8.03hijk	± 18.66	± 27.85	± 1.11g	± 3.66	± 8.32jkl	± 19.33	± 28.99	± 1.15g	± 4.10h	± 9.06ghij	± 20.39	± 29.77
	T_8	25.85	87.98	207.95	483.23	707.36	27.60	93.22	217.32	507.40	730.12	29.99	111.13	232.65	532.14	754.01
		± 0.77d	± 3.99c	± 9.65c	± 21.07	± 30.98	± 0.86de	± 4.27	± 9.56cde	± 20.59	± 32.17	± 0.98cd	± 4.62cd	± 12.09cd	± 21.88	± 33.41
V_3	T_0	19.18	49.31	131.50	347.01	551.74	20.01	52.21	145.22	378.70	572.48	18.82	63.50	157.92	409.58	597.74
		± 0.78n	± 1.99m	± 5.32q	± 14.02	± 22.30	± 0.81m	± 2.11	± 5.87o	± 15.31	± 23.14	± 0.76l	± 2.57o	± 6.38o	± 16.55	± 24.16
	T_1	21.22	65.33	168.84	395.54	603.4	22.36	73.76	183.67	425.05	637.49	24.15	84.53	194.08	455.35	645.58
		± 0.59jkl	± 3.07ij	± 7.53m	± 19.08	± 27.33	± 0.65jkl	± 3.47	± 8.34l	± 18.70	± 29.19	± 0.75ij	± 4.06jk	± 8.91lm	± 21.51	± 29.06
	T_2	22.13	76.33	180.17	424.12	651.88	24.33	82.27	197.17	453.63	672.83	24.88	93.96	206.71	475.19	698.09
		± 0.83hi	± 2.86g	± 6.76kl	± 15.92	± 24.46	± 0.91hi	± 3.09	± 7.40hijk	± 17.02	± 25.25	± 0.93hi	± 3.53h	± 7.76g-k	± 17.83	± 26.20
	T_3	24.10	79.67	194.90	446.46	674.47	26.07	86.17	203.98	467.37	696.77	27.05	100.83	212.70	506.74	723.67
		± 0.42e	± 1.38ef	± 3.38def	± 7.73	± 11.68	± 0.45g	± 1.49	± 3.53fghi	± 8.10	± 12.07	± 0.47fg	± 1.75fg	± 3.68fghi	± 8.78	± 12.53
	T_4	28.33	87.83	205.31	495.64	765.39	30.32	97.01	223.40	526.57	788.63	31.92	114.45	234.36	545.37	810.39
		± 0.98b	± 3.04c	± 7.11c	± 17.17	± 26.51	± 1.05ab	± 3.36	± 7.74abc	± 18.24	± 27.32	± 1.11b	± 3.97bc	± 8.12bc	± 18.89	± 28.07
	T_5	25.42	82.82	197.21	458.30	716.77	27.32	91.82	209.20	487.38	727.71	29.95	106.70	219.65	518.13	757.54
		± 1.25d	± 4.07d	± 9.68de	± 22.49	± 35.18	± 1.34ef	± 4.51	± 10.27efg	± 23.92	± 35.71	± 1.47cd	± 5.24	± 10.78ef	± 25.43	± 37.18
	T_6	21.97	69.63	174.24	412.87	630.54	23.23	75.50	190.61	441.94	656.13	24.88	89.68	204.24	469.88	687.72
		± 0.70hij	± 2.21h	± 5.53lm	± 13.11	± 20.02	± 0.74ijk	± 2.40	± 6.05kl	± 14.03	± 20.84	± 0.97hi	± 2.85i	± 6.49ijk	± 14.92	± 21.84
	T_7	23.81	80.89	187.68	449.44	694.76	26.26	88.00	200.31	470.60	705.01	28.28	100.39	210.69	496.52	739.72
		± 1.03ef	± 3.50de	± 8.13ghij	± 19.46	± 30.08	± 1.14fg	± 3.81	± 8.68ghij	± 20.38	± 30.53	± 1.23ef	± 4.35fg	± 9.12fghi	± 21.50	± 32.03
	T_8	30.34	96.97	222.63	529.52	780.03	31.11	101.35	230.93	558.67	807.73	37.76	125.04	252.05	582.68	843.23
		± 1.00a	± 4.46a	± 9.84a	± 21.80	± 34.76	± 1.04a	± 4.69	± 9.11a	± 22.10	± 36.20	± 1.39a	± 5.21a	± 10.26a	± 24.50	± 34.81
LS		**	**	*	NS	NS	**	NS	**	NS	NS	**	*	**	NS	NS
CV (%)		1.91	2.22	2.02	1.86	1.83	2.23	2.41	2.27	2.21	2.15	2.59	2.50	2.26	2.17	2.13

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, ** = 1% Level of significance, * = 5% Level of significance, CV = Co-efficient of variation.

4.3.2 Leaf area index

Leaf area index (LAI) was significantly affected by the selected varieties of wheat in the length of the research. The upper limit of LAI was recorded from V_3 and the lower limit from V_1 (Fig. 9, 10 and 11). In case of V_3, LAI achieved the maximum value (3.48) at 55 DAS in 2018-2019. On the contrary, the minimum value (2.84) at same DAS was recorded in 2016-2017. Normally, the leaf area index enlarged gradually with age of the wheat plants and reached the peak at 55 DAS. After that, LAI decreased slowly and this happened for all varieties. Wheat plants at 55 DAS produced higher leaves/plant that resulted in the highest LAI.

All soil amendments provided significant results for leaf area index at every sampling date in each year of study. The treatment T_8 performed better, followed by T_4 than that of T_0 in respect of LAI at all DAS (Fig. 12, 13 and 14). The highest value (4.34) of LAI was recorded from T_8 and the lowest one (2.14) was from T_0 at the peak period (55 DAS) during 2018-2019 and 2016-2017, respectively. The leaf area had an ascending tendency up to 55 DAS, whereas descending nature exhibited in the next 70 DAS and 85 DAS in the three years of the experiment. Due to slow release of plant nutrient from organic manure, LAI at 85 DAS was not higher than chemical fertilizer but statistically identical with chemical fertilizer during first cropping season by T_8 (3.73) and T_4 (3.39) and also from T_8 (2.58) and T_4 (2.46) in second year.

The combination of variety and different soil amendments had significant effects on LAI at 25 DAS, 40 and 55 DAS in 2016-2017 (Table 22). Initially at 25 and 40 DAS, the comparative higher LAI was noticed in V_3T_8 (0.70 and 2.20) and at 55 DAS, V_3T_8 once more gave the comparative greater value (3.88). The variation of LAI for interaction of variety and different soil amendments was significant at 25 and 55 DAS in 2017-2018, which maintained the parallel pattern as in 2016-2017. In the year 2018-2019, among the organic amendments of soil, poultry manure (T_4) greatly influenced the LAI, however, in every case, all other treatments showed good effect than no soil amendment (T_0). In the last year 2018-2019, LAI influenced significantly as a result of selected treatments combinations. The treatment combination V_3T_8 showed the highest value (4.38) of LAI than the other treatment combinations, whereas V_2T_0 gave the lowest value (2.34) at peak period (55 DAS) of LAI. Furthermore, the above higher and lower order of LAI was noticed during rest of the sampling dates (Table 22).

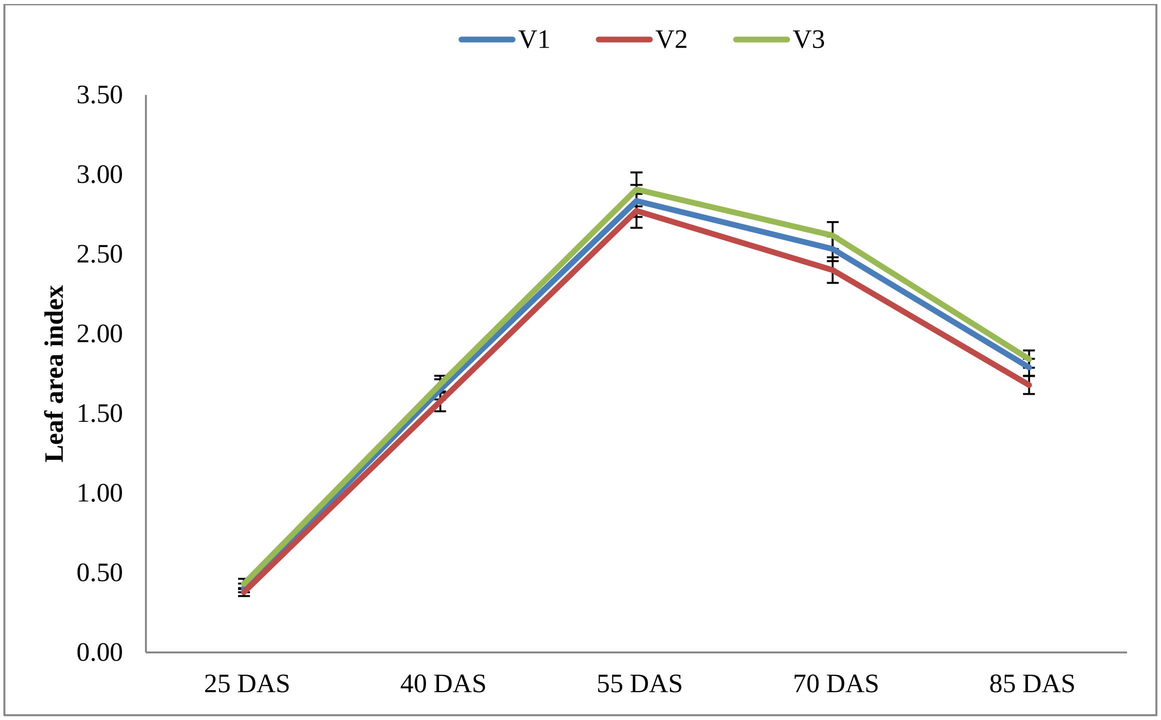


Fig. 9: Effect of variety on leaf area index of wheat in 2016-2017.

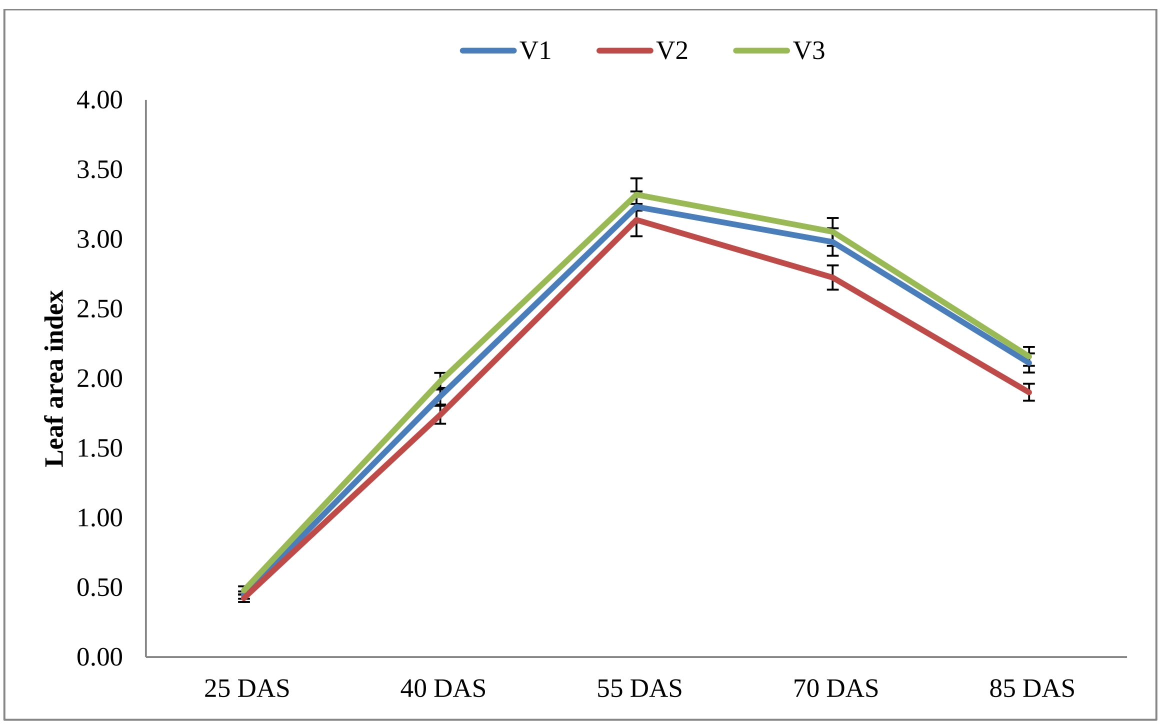


Fig. 10: Effect of variety on leaf area index of wheat in 2017-2018.

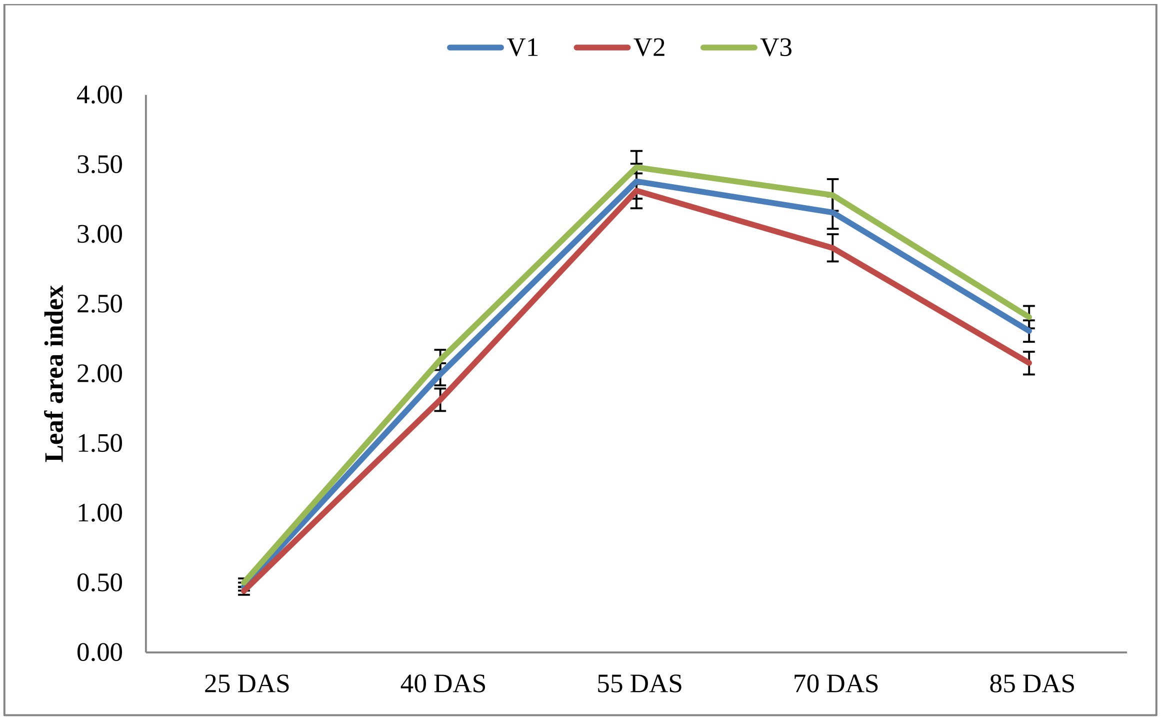


Fig. 11: Effect of variety on leaf area index of wheat in 2018-2019.

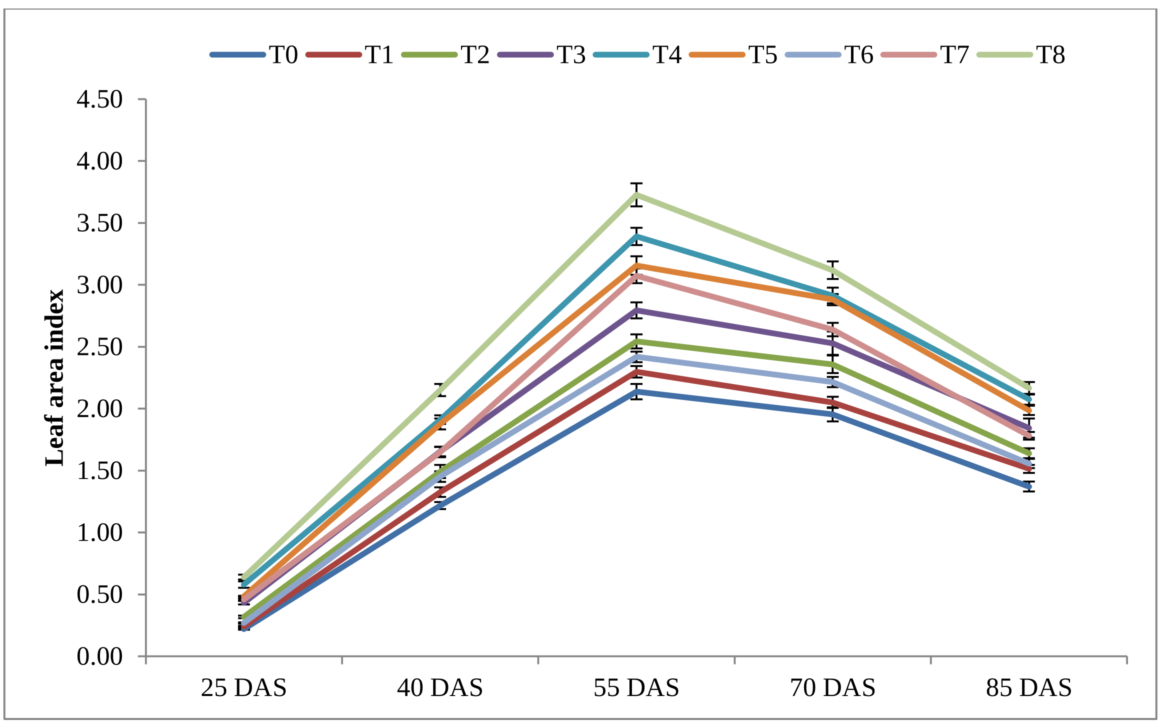


Fig. 12: Effect of organic and probiotic soil amendments on leaf area index of wheat in 2016-2017.

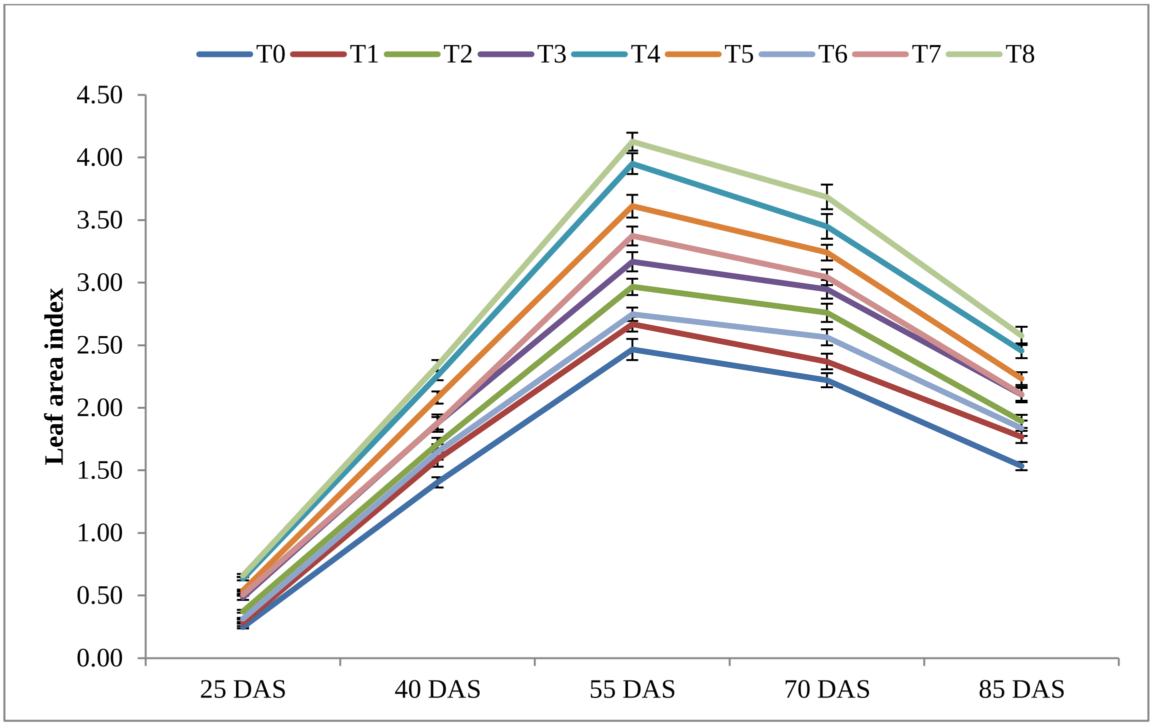


Fig. 13: Effect of organic and probiotic soil amendments on leaf area index of wheat in 2017-2018.

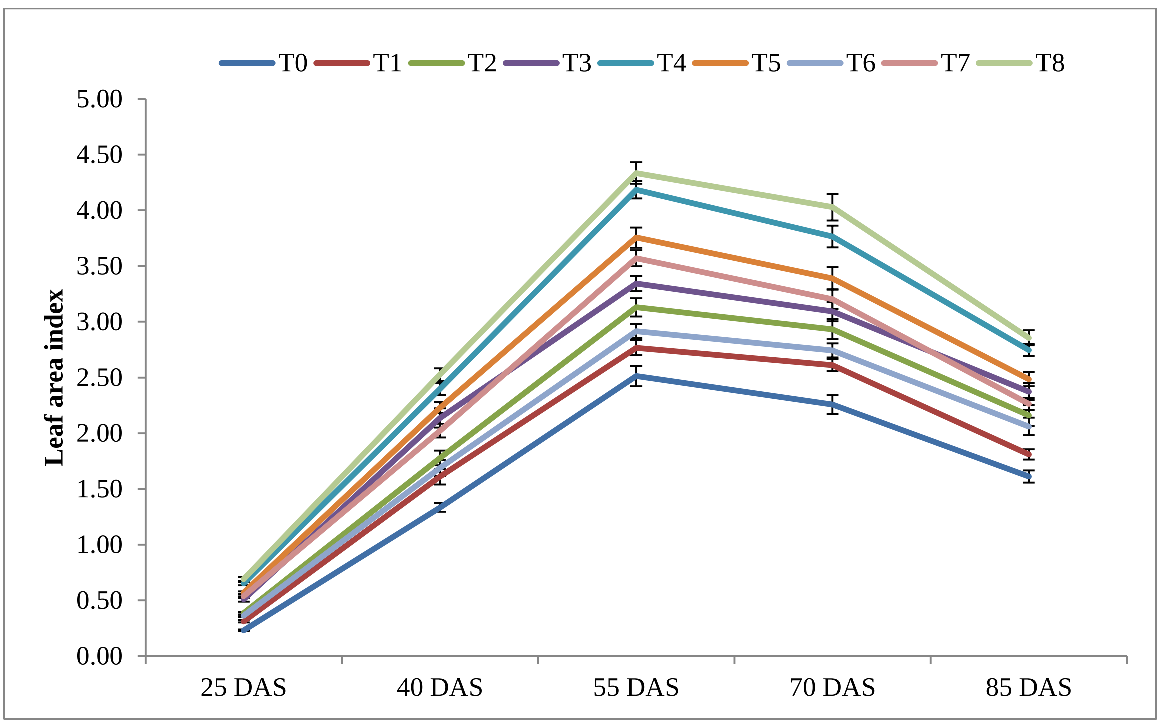


Fig. 14: Effect of organic and probiotic soil amendments on leaf area index of wheat in 2018-2019.

Table 22: Interaction effects of variety and soil amendments on leaf area index of wheat.

Variety & Treatment		2016-2017					2017-2018					2018-2019				
		Days after sowing (DAS)														
		25	40	55	70	85	25	40	55	70	85	25	40	55	70	85
	T_0	0.23 ± 0.01n	1.21 ± 0.03lm	2.20 ± 0.10n	2.01 ± 0.10	1.37 ± 0.02	0.27 ± 0.01op	1.45 ± 0.06	2.54 ± 0.12m	2.24 ± 0.11	1.52 ± 0.03	0.24 ± 0.01p	1.35 ± 0.07m	2.42 ± 0.12p	2.20 ± 0.11q	1.68 ± 0.07n
	T_1	0.24 ± 0.01mn	1.30 ± 0.06klm	2.29 ± 0.10mn	2.08 ± 0.09	1.56 ± 0.05	0.28 ± 0.01nop	1.54 ± 0.08	2.65 ± 0.11l	2.41 ± 0.08	1.50 ± 0.05	0.31 ± 0.01n	1.60 ± 0.06jk	2.70 ± 0.12o	2.66 ± 0.12mno	1.84 ± 0.07l
	T_2	0.33 ± 0.00j	1.56 ± 0.05g-j	2.56 ± 0.13ij	2.33 ± 0.08	1.65 ± 0.02	0.37 ± 0.01k	1.73 ± 0.06	3.02 ± 0.10i	2.74 ± 0.03	1.94 ± 0.07	0.38 ± 0.02k	1.80 ± 0.07i	3.21 ± 0.18j	3.01 ± 0.12k	2.25 ± 0.11j
	T_3	0.42 ± 0.01h	1.64 ± 0.03e-h	2.78 ± 0.10gh	2.60 ± 0.13	1.89 ± 0.08	0.47 ± 0.01i	1.99 ± 0.08	3.13 ± 0.12h	3.05 ± 0.11	2.17 ± 0.10	0.53 ± 0.02h	2.24 ± 0.10e	3.38 ± 0.13i	3.12 ± 0.13j	2.48 ± 0.09fg
V_1	T_4	0.54 ± 0.01d	1.94 ± 0.07bc	3.38 ± 0.14cd	2.88 ± 0.09	2.03 ± 0.08	0.62 ± 0.01cd	2.24 ± 0.07	3.98 ± 0.10c	3.56 ± 0.11	2.51 ± 0.11	0.63 ± 0.03cd	2.41 ± 0.09bc	4.17 ± 0.10cd	3.84 ± 0.11d	2.77 ± 0.09c
	T_5	0.49 ± 0.01e	1.88 ± 0.07bcd	3.15 ± 0.15ef	2.92 ± 0.08	2.02 ± 0.07	0.52 ± 0.01fgh	2.05 ± 0.10	3.56 ± 0.15f	3.28 ± 0.09	2.27 ± 0.08	0.57 ± 0.02ef	2.28 ± 0.06de	3.64 ± 0.17g	3.47 ± 0.16g	2.50 ± 0.11f
	T_6	0.27 ± 0.01kl	1.38 ± 0.07jkl	2.41 ± 0.08kl	2.23 ± 0.07	1.58 ± 0.07	0.32 ± 0.01lm	1.65 ± 0.07	2.73 ± 0.13kl	2.65 ± 0.05	1.92 ± 0.08	0.38 ± 0.02k	1.66 ± 0.07j	2.98 ± 0.10k	2.74 ± 0.10m	2.13 ± 0.07k
	T_7	0.47 ± 0.01ef	1.74 ± 0.06d-g	3.08 ± 0.12f	2.62 ± 0.08	1.81 ± 0.06	0.50 ± 0.01ghi	1.87 ± 0.06	3.34 ± 0.12g	3.11 ± 0.06	2.14 ± 0.07	0.53 ± 0.02h	2.07 ± 0.10f	3.53 ± 0.14h	3.26 ± 0.13i	2.24 ± 0.10j
	T_8	0.65 ± 0.01b	2.22 ± 0.07a	3.67 ± 0.17b	3.14 ± 0.08	2.20 ± 0.09	0.65 ± 0.01bc	2.33 ± 0.10	4.14 ± 0.11ab	3.79 ± 0.14	2.66 ± 0.11	0.68 ± 0.02b	2.56 ± 0.08a	4.39 ± 0.20a	4.12 ± 0.20b	2.87 ± 0.11b
	T_0	0.22 ± 0.01n	1.15 ± 0.04m	1.95 ± 0.04o	1.81 ± 0.10	1.26 ± 0.06	0.22 ± 0.01q	1.30 ± 0.05	2.22 ± 0.10n	2.11 ± 0.11	1.47 ± 0.07	0.22 ± 0.01q	1.24 ± 0.05n	2.34 ± 0.12q	2.05 ± 0.09r	1.45 ± 0.06o
	T_1	0.24 ± 0.01mn	1.25 ± 0.05lm	2.27 ± 0.10mn	2.0270 ± 0.08	1.47 ± 0.08	0.27 ± 0.01nop	1.44 ± 0.06	2.64 ± 0.13l	2.22 ± 0.10	1.61 ± 0.07	0.28 ± 0.01o	1.40 ± 0.07m	2.75 ± 0.12o	2.57 ± 0.08op	1.72 ± 0.08mn
	T_2	0.28 ± 0.00k	1.30 ± 0.05klm	2.46 ± 0.07jk	2.18 ± 0.09	1.53 ± 0.06	0.33 ± 0.01l	1.60 ± 0.07	2.86 ± 0.10j	2.59 ± 0.11	1.74 ± 0.05	0.35 ± 0.01l	1.57 ± 0.07k	2.95 ± 0.10kl	2.66 ± 0.11mn	1.84 ± 0.07l
	T_3	0.39 ± 0.00i	1.56 ± 0.08g-j	2.72 ± 0.10h	2.24 ± 0.11	1.59 ± 0.05	0.43 ± 0.01j	1.65 ± 0.06	3.10 ± 0.13hi	2.72 ± 0.10	1.94 ± 0.06	0.44 ± 0.02i	1.84 ± 0.04hi	3.24 ± 0.12j	2.88 ± 0.13l	2.11 ± 0.06k
V_2	T_4	0.52 ± 0.00d	1.87 ± 0.05bcd	3.33 ± 0.13d	2.79 ± 0.11	2.03 ± 0.10	0.60 ± 0.01d	2.17 ± 0.06	3.85 ± 0.19d	3.14 ± 0.13	2.28 ± 0.06	0.63 ± 0.0361d	2.35 ± 0.11cd	4.10 ± 0.16d	3.49 ± 0.11g	2.62 ± 0.10e
	T_5	0.49 ± 0.01e	1.94 ± 0.09bc	3.13 ± 0.14ef	2.85 ± 0.12	1.94 ± 0.10	0.53 ± 0.01ef	2.04 ± 0.08	3.52 ± 0.15f	3.09 ± 0.13	2.11 ± 0.11	0.55 ± 0.02g	2.11 ± 0.07f	3.75 ± 0.16f	3.13 ± 0.14j	2.31 ± 0.07ij
	T_6	0.26 ± 0.01klm	1.41 ± 0.07jkl	2.40 ± 0.07kl	2.18 ± 0.09	1.49 ± 0.08	0.30 ± 0.01mn	1.46 ± 0.06	2.73 ± 0.08kl	2.38 ± 0.09	1.64 ± 0.04	0.33 ± 0.01mn	1.50 ± 0.07l	2.88 ± 0.14lm	2.64 ± 0.10no	1.79 ± 0.08lm
	T_7	0.46 ± 0.01fg	1.67 ± 0.08e-h	3.05 ± 0.13f	2.60 ± 0.12	1.73 ± 0.07	0.49 ± 0.02hi	1.76 ± 0.08	3.28 ± 0.14g	2.85 ± 0.12	1.97 ± 0.09	0.52 ± 0.02h	1.87 ± 0.10hi	3.56 ± 0.14gh	2.99 ± 0.11k	2.14 ± 0.06k
	T_8	0.57 ± 0.01c	2.04 ± 0.10ab	3.64 ± 0.18b	2.95 ± 0.13	2.07 ± 0.10	0.63 ± 0.01cd	2.23 ± 0.02	4.05 ± 0.11bc	3.41 ± 0.13	2.35 ± 0.11	0.65 ± 0.02c	2.43 ± 0.10b	4.24 ± 0.16bc	3.73 ± 0.16e	2.72 ± 0.13cd

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Variety & Treatment		2016-2017					2017-2018					2018-2019				
		Days after sowing (DAS)														
		25	40	55	70	85	25	40	55	70	85	25	40	55	70	85
V_3	T_0	0.22 ± 0.01n	1.30 ± 0.03klm	2.26 ± 0.09mn	2.03 ± 0.06	1.49 ± 0.05	0.25 ± 0.01p	1.46 ± 0.06	2.64 ± 0.12l	2.31 ± 0.07	1.61 ± 0.05	0.24 ± 0.01p	1.41 ± 0.07m	2.78 ± 0.12no	2.52 ± 0.10p	1.71 ± 0.07mn
	T_1	0.24 ± 0.01mn	1.44 ± 0.05ijk	2.34 ± 0.08ml	2.05 ± 0.09	1.52 ± 0.04	0.29 ± 0.01mno	1.78 ± 0.02	2.71 ± 0.11kl	2.47 ± 0.11	1.85 ± 0.05	0.33 ± 0.01lm	1.84 ± 0.04hi	2.86 ± 0.14mn	2.61 ± 0.12no	1.87 ± 0.09l
	T_2	0.35 ± 0.01j	1.62 ± 0.03f-i	2.61 ± 0.11i	2.56 ± 0.08	1.74 ± 0.05	0.41 ± 0.01j	1.81 ± 0.09	3.03 ± 0.15i	2.95 ± 0.13	2.00 ± 0.08	0.42 ± 0.02j	1.97 ± 0.05g	3.23 ± 0.12j	3.13 ± 0.11j	2.39 ± 0.10hi
	T_3	0.49 ± 0.01e	1.76 ± 0.03c-f	2.88 ± 0.15g	2.75 ± 0.07	2.05 ± 0.09	0.55 ± 0.03ef	2.00 ± 0.09	3.27 ± 0.18g	3.06 ± 0.08	2.21 ± 0.11	0.55 ± 0.03g	2.33 ± 0.11d	3.41 ± 0.13i	3.28 ± 0.13hi	2.53 ± 0.07f
	T_4	0.68 ± 0.01a	1.92 ± 0.08bcd	3.47 ± 0.14c	3.07 ± 0.10	2.16 ± 0.05	0.68 ± 0.015ab	2.36 ± 0.02	4.02 ± 0.17c	3.65 ± 0.12	2.57 ± 0.06	0.69 ± 0.02b	2.43 ± 0.11b	4.28 ± 0.17b	3.97 ± 0.17c	2.85 ± 0.07b
	T_5	0.47 ± 0.01ef	1.82 ± 0.08cde	3.20 ± 0.15e	2.88 ± 0.05	2.00 ± 0.04	0.56 ± 0.01e	2.15 ± 0.09	3.76 ± 0.18e	3.35 ± 0.06	2.320 ± 0.04	0.58 ± 0.02e	2.30 ± 0.11de	3.88 ± 0.178e	3.58 ± 0.13f	2.64 ± 0.06de
	T_6	0.28 ± 0.00k	1.57 ± 0.05g-j	2.44 ± 0.11kl	2.24 ± 0.08	1.60 ± 0.04	0.32 ± 0.01lm	1.83 ± 0.03	2.78 ± 0.10jk	2.66 ± 0.12	1.95 ± 0.09	0.38 ± 0.02k	1.91 ± 0.09gh	2.89 ± 0.11lm	2.85 ± 0.13l	2.27 ± 0.05j
	T_7	0.44 ± 0.01gh	1.54 ± 0.03hij	3.08 ± 0.10f	2.70 ± 0.10	1.81 ± 0.03	0.53 ± 0.01fg	1.99 ± 0.07	3.50 ± 0.14f	3.17 ± 0.04	2.21 ± 0.06	0.56 ± 0.03gf	2.13 ± 0.09f	3.63 ± 0.14g	3.36 ± 0.17h	2.41 ± 0.06gh
	T_8	0.70 ± 0.01a	2.20 ± 0.07a	3.88 ± 0.17a	3.27 ± 0.10	2.23 ± 0.08	0.70 ± 0.01a	2.45 ± 0.03	4.19 ± 0.18a	3.85 ± 0.14	2.71 ± 0.04	0.74 ± 0.03a	2.59 ± 0.13a	4.38 ± 0.19a	4.24 ± 0.18a	2.99 ± 0.09a
LS		**	*	**	NS	NS	**	NS	**	NS	NS	**	**	**	**	**
CV (%)		3.70	6.39	2.18	6.29	6.59	4.08	6.38	1.63	5.81	6.43	2.35	2.40	1.41	1.64	2.13

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, ** = 1% Level of significance, * = 5% Level of significance, CV = Co-efficient of variation.

4.3.3 Crop growth rate

In this present study, crop growth rate (CGR) was found as significant at all sampling dates by all varieties during 2016-2017 (Fig. 15). From 25-40 to 55-70 DAS, CGR increased sharply and then went down slowly. Where the maximum (16.97 $g/m^2/d$) and the minimum (15.83 $g/m^2/d$) CGR recorded from V_3 and V_2, respectively when the wheat plant reached the peak growth (55-70 DAS). The maximum and statistically equal crop growth rate derived from V_3 (3.50 $g/m^2/d$) and V_1 (3.45 g/m2/d) at 25-40 DAS. Wheat plant also showed significant variation in CGR caused by varietal influence in 2017-2018 (Fig. 16), where descending order of CGR was found as$V_3 > V_1 > V_2$. Here V_3 variety had produced the greater CGR (17.97 $g/m^2/d$) and less CGR (17.09 $g/m^2/d$) recorded by V_2. A similar tendency was obtained from the selected varieties of wheat in 2018-2019, which refers to the year 2016-2017. But only at 40-55 DAS, V_3 (7.51 $g/m^2/d$) and V_1 (7.47 $g/m^2/d$) showed the similarity of significance (Fig. 17).

The data indicated that soil amendments had a significant effect on wheat CGR at all DAS in the whole experimental period. Most of the sampling dates revealed that the treatment T_8 had the highest activity in CGR followed in sequence by T_4, T_5, T_7, T_3, T_2, T_6 and T_1 and the lowest was in T_0 (Fig. 18, 19 and 20). At the end (70-85 DAS) of CGR sampling, T_4 showed the greater influence. Through the three years of study maximum CGR value (21.24 $g/m^2/d$) was reported at 55-70 DAS by T_8 and T_4 (19.89 $g/m^2/d$) in 2018-2019. Whereas the minimum value (16.386 $g/m^2/d$) was recorded at the same DAS from T_0 in 2018-2019. Variation in CGR among the soil amendments was exhibited to a higher extent at 55-70 DAS and afterwards decreased due to leaf senescence and tiller drying.

The crop growth rate showed significant variation at various combinations of treatments and varieties during 2016-2017 at all DAS. Increasing development of crop growth rate was noticed from initial to till 40-55 DAS, where the combination V_3T_8 (20.46 $g/m^2/d$), V_1T_8 (18.86 $g/m^2/d$) and V_2T_8 (18.03 $g/m^2/d$) produced greater CGR, while the lowest value was observed in V_2T_0 (13.36 $g/m^2/d$), V_1T_0 (13.72 $g/m^2/d$) and V_3T_0 (14.37 $g/m^2/d$).

With the statistical significance, maximum CGR were recorded from V_3T_8 (21.85 g/m^2/d) followed by V_1T_8 (20.62 g/m^2/d) and V_2T_8 (19.94 g/m^2/d) at 55-70 DAS in 2017-2018. Comparable results were found in 2018-2019 with 2016-2017 regarding CGR from starting to till 55-70 DAS. But the maximum increased values of CGR was documented with statistical identity in case of V_3T_8 (22.04 g/m^2/d) and V_1T_8 (21.72 g/m^2/d) at 55-70 DAS, oppositely the minimum decreased of CGR was showed statistical identity in case of V_3T_4 (17.67 g/m^2/d) and V_3T_8 (17.37 g/m^2/d) at 70-85 DAS (Table 23).

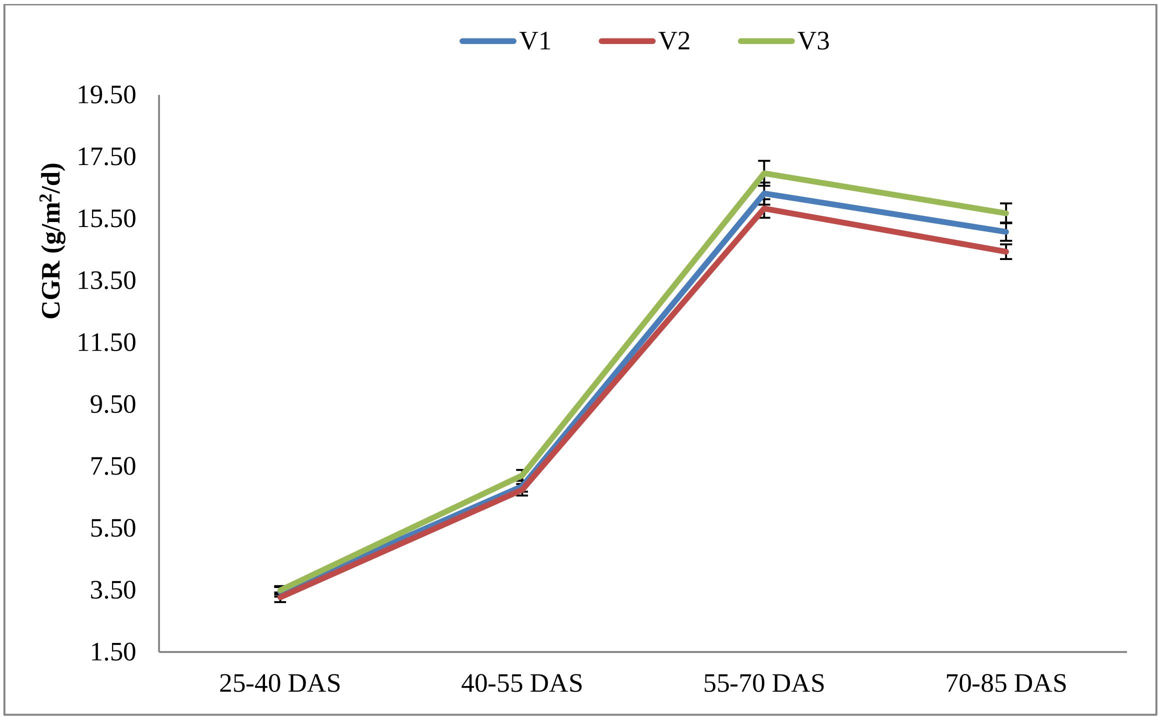

Fig. 15: Effect of variety on crop growth rate of wheat in 2016-2017.

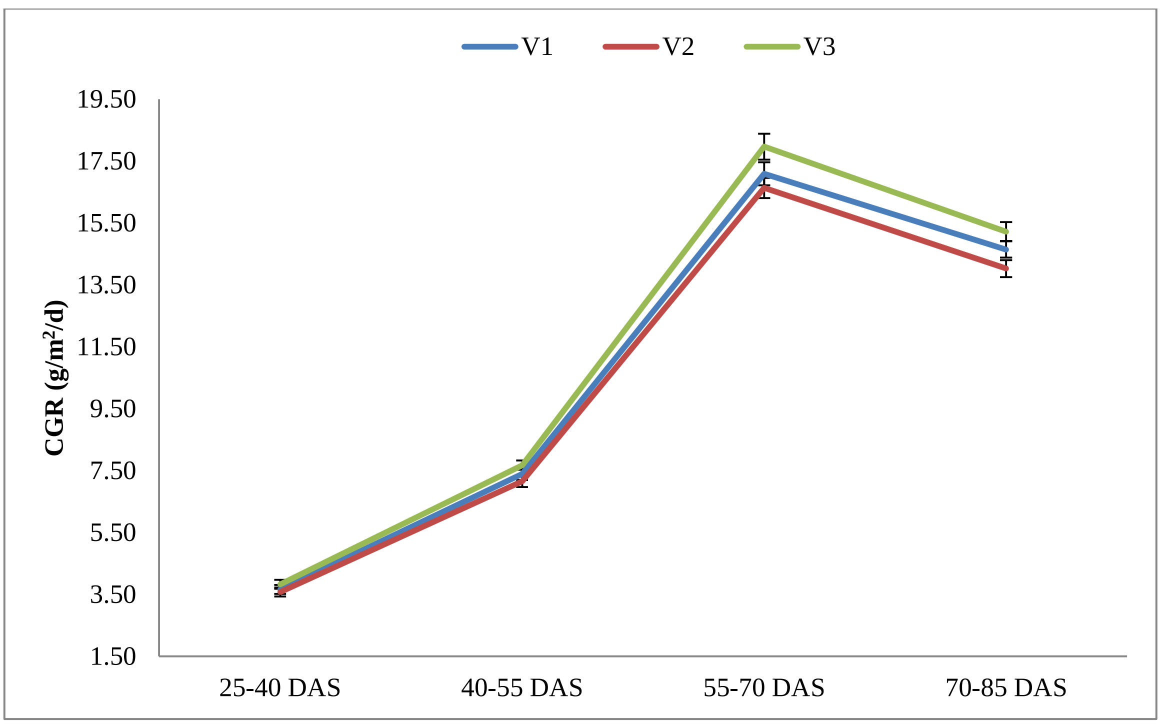

Fig. 16: Effect of variety on crop growth rate of wheat in 2017-2018.

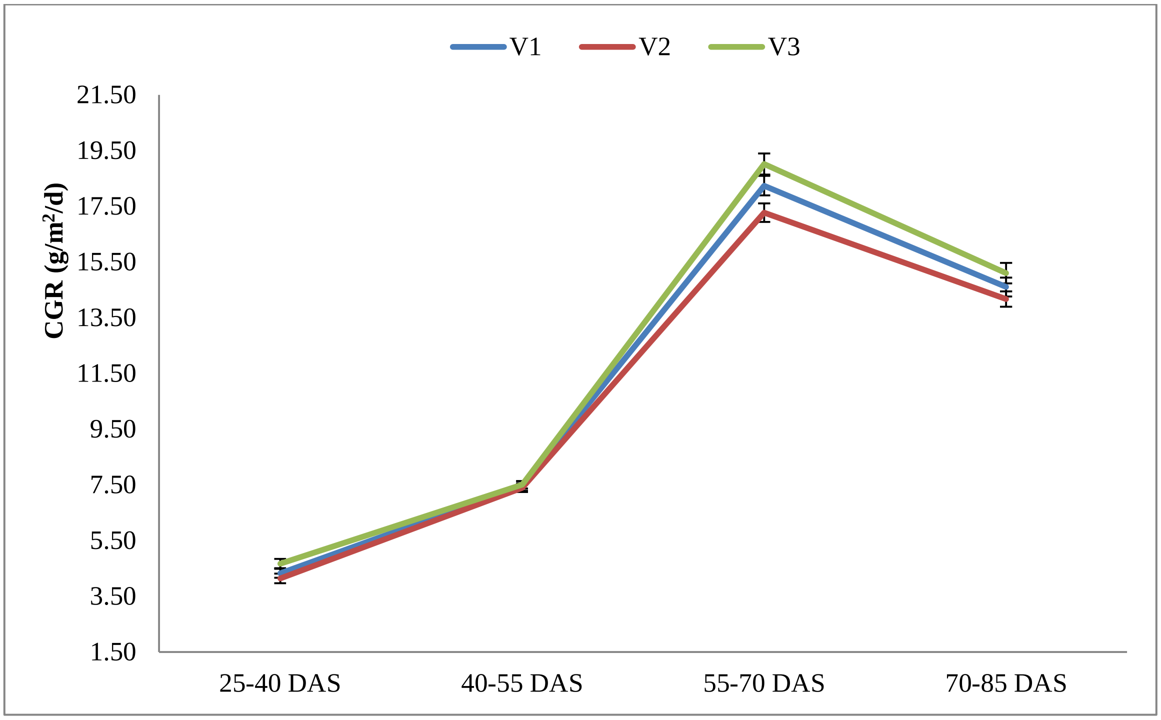

Fig. 17: Effect of variety on crop growth rate of wheat in 2018-2019.

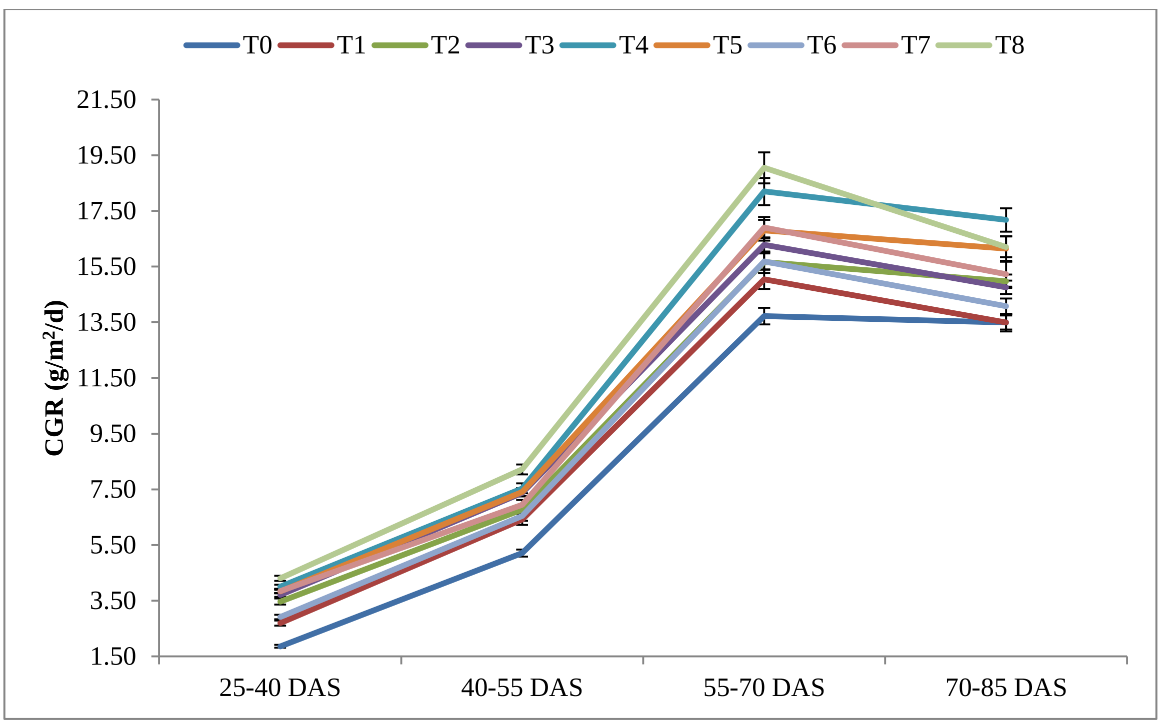

Fig. 18: Effect of organic and probiotic soil amendments on crop growth rate of wheat in 2016-2017.

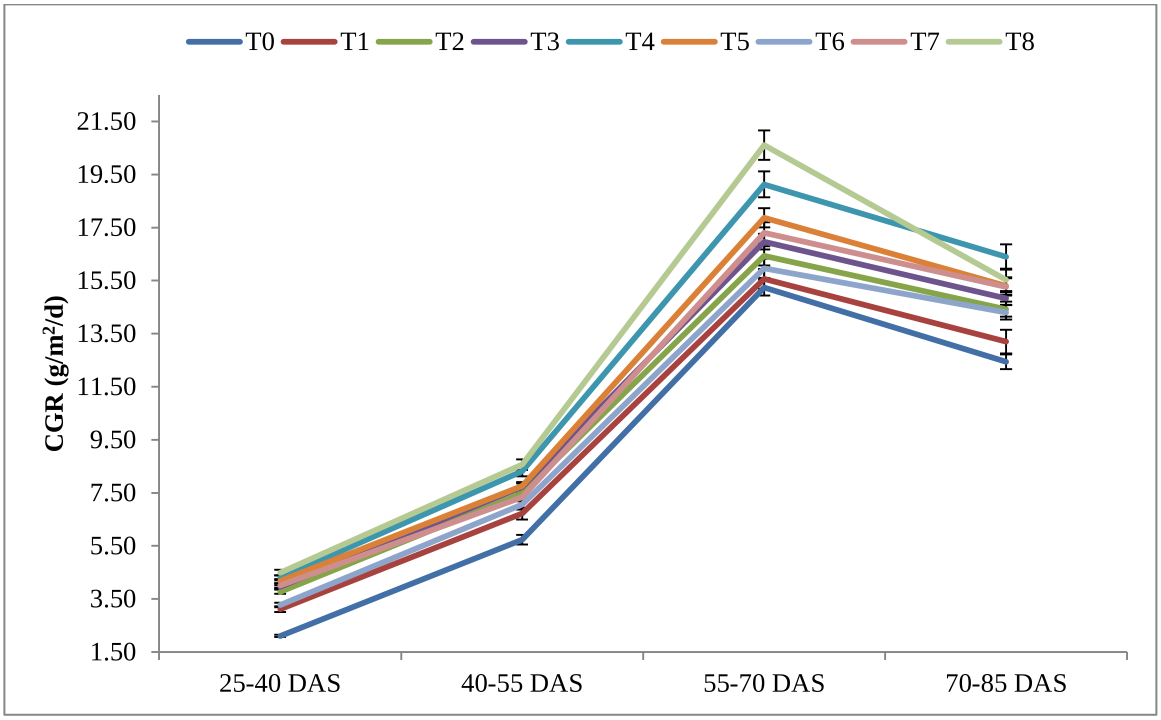

Fig. 19: Effect of organic and probiotic soil amendments on crop growth rate of wheat in 2017-2018.

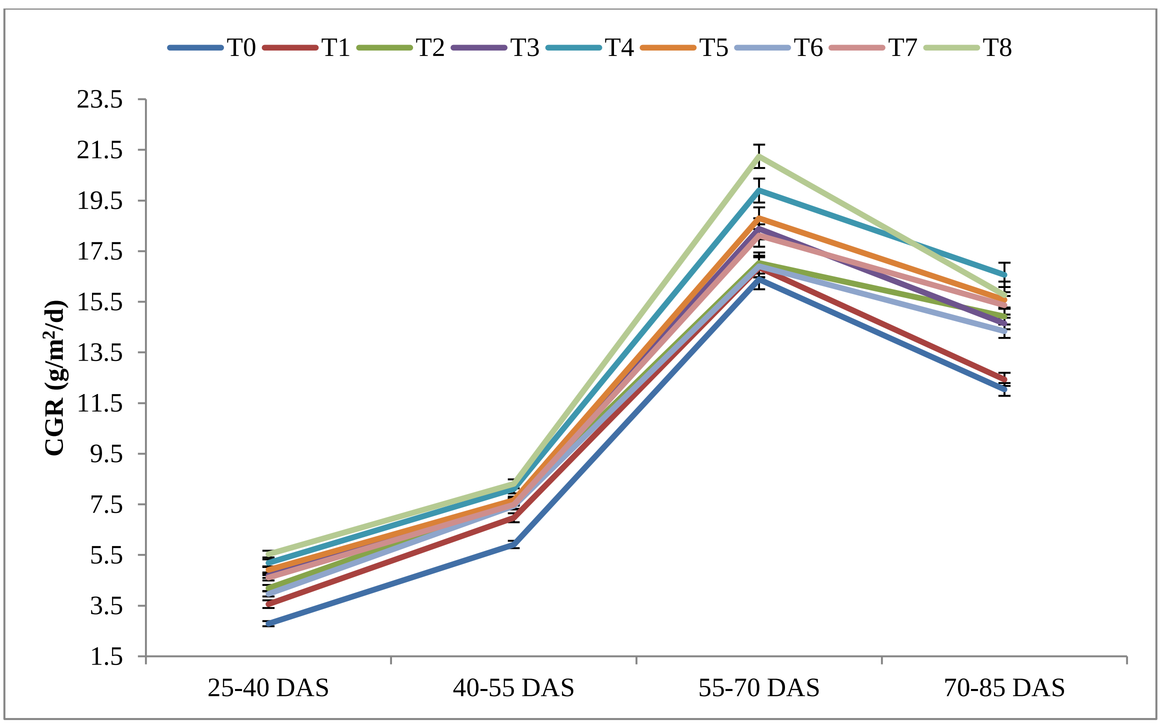

Fig. 20: Effect of organic and probiotic soil amendments on crop growth rate of wheat in 2018-2019.

Table 23: Interaction effects of variety and soil amendments on crop growth rate of wheat (g/m^2/d).

Variety & Treatment		2016-2017				2017-2018				2018-2019			
		Days after sowing (DAS)											
		25-40	40-55	55-70	70-85	25-40	40-55	55-70	70-85	25-40	40-55	55-70	70-85
V_1	T_0	1.74 ± 0.09l	5.23 ± 0.25m	13.45 ± 0.67p	13.55 ± 0.54mno	2.06 ± 0.07p	5.77 ± 0.23k	15.40 ± 0.58qr	12.55 ± 0.59m	2.93 ± 0.13n	5.68 ± 0.25k	16.85 ± 0.83j	11.75 ± 0.51m
	T_1	2.75 ± 0.15i	6.34 ± 0.32j	15.33 ± 0.75k-n	13.44 ± 0.67no	3.08 ± 0.10n	6.61 ± 0.31i	15.35 ± 0.75qr	13.55 ± 0.66l	3.54 ± 0.17l	6.88 ± 0.34i	16.99 ± 0.74ij	12.49 ± 0.61kl
	T_2	3.68 ± 0.14g	6.56 ± 0.27i	15.46 ± 0.61j-m	15.06 ± 0.54efg	3.810 ± 0.07j	7.30 ± 0.25gh	16.34 ± 0.77mno	14.48 ± 0.32hij	4.07 ± 0.14i	7.65 ± 0.29ef	17.13 ± 0.64ij	14.79 ± 0.72f-i
	T_3	3.73 ± 0.16fg	7.32 ± 0.32ef	15.98 ± 0.68hij	14.61 ± 0.59g-j	3.94 ± 0.10hij	7.85 ± 0.30e	16.86 ± 0.65klm	14.64 ± 0.59ghi	4.65 ± 0.19f	7.82 ± 0.32de	18.07 ± 0.73ef	14.52 ± 0.59ghi
	T_4	4.08 ± 0.20cd	7.45 ± 0.39de	18.07 ± 0.87c	17.08 ± 0.76b	4.27 ± 0.12de	8.43 ± 0.34bc	18.93 ± 0.83cd	16.52 ± 0.79b	5.17 ± 0.24c	8.30 ± 0.38ab	19.84 ± 0.92c	16.65 ± 0.77b
	T_5	3.87 ± 0.12d-g	7.32 ± 0.22ef	17.06 ± 0.50de	16.27 ± 0.44d	4.11 ± 0.09fg	7.64 ± 0.21ef	17.42 ± 0.49hij	15.06 ± 0.47efg	4.95 ± 0.14d	7.52 ± 0.22fg	18.51 ± 0.53e	15.88 ± 0.46c
	T_6	2.85 ± 0.12i	6.60 ± 0.26i	15.74 ± 0.60i-l	14.08 ± 0.55j-m	3.27 ± 0.10m	6.81 ± 0.25i	15.96 ± 0.59nop	14.60 ± 0.53hij	3.78 ± 0.14k	7.51 ± 0.28fg	17.22 ± 0.65hij	14.44 ± 0.54ij
	T_7	4.00 ± 0.14cde	6.61 ± 0.25i	16.88 ± 0.59def	15.19 ± 0.53ef	3.99 ± 0.13ghi	7.35 ± 0.23gh	16.94 ± 0.59jkl	15.29 ± 0.53de	4.47 ± 0.16g	7.46 ± 0.26fg	17.85 ± 0.62fg	15.76 ± 0.55cd
	T_8	4.32 ± 0.22ab	8.273 ± 0.43a	18.86 ± 0.95b	16.43 ± 0.74cd	4.41 ± 0.17bc	8.79 ± 0.41a	20.62 ± 0.93b	15.13 ± 0.81ef	5.40 ± 0.27b	8.37 ± 0.38a	21.72 ± 0.38a	15.15 ± 0.69ef
V_2	T_0	1.83 ± 0.04kl	4.92 ± 0.11n	13.36 ± 0.30p	13.28 ± 0.24no	2.13 ± 0.08lp	5.23 ± 0.10l	14.75 ± 0.27s	11.85 ± 0.27n	2.46 ± 0.05o	5.77 ± 0.12k	15.53 ± 0.31l	11.82 ± 0.24m
	T_1	2.39 ± 0.11j	6.01 ± 0.23k	14.84 ± 0.57no	13.01 ± 0.45o	2.85 ± 0.07o	6.22 ± 0.23j	15.26 ± 0.557rs	11.90 ± 0.49n	3.14 ± 0.12m	6.75 ± 0.25i	16.17 ± 0.61k	12.12 ± 0.46lm
	T_2	3.12 ± 0.15h	6.85 ± 0.30h	15.27 ± 0.64lmn	14.66 ± 0.57f-i	3.64 ± 0.12k	7.48 ± 0.28fg	15.86 ± 0.73opq	14.17 ± 0.44jk	3.91 ± 0.15jk	7.63 ± 0.31ef	16.06 ± 0.65k	15.11 ± 0.55ef
	T_3	3.69 ± 0.10g	7.12 ± 0.19fg	16.10 ± 0.43hi	14.46 ± 0.38h-k	3.93 ± 0.17hij	7.46 ± 0.19fg	16.48 ± 0.42lmn	14.56 ± 0.38hij	4.49 ± 0.18g	7.54 ± 0.20fg	17.48 ± 0.45ghi	14.95 ± 0.39efg
	T_4	3.96 ± 0.18c-f	7.33 ± 0.35ef	17.18 ± 0.79de	16.46 ± 0.66cd	4.18 ± 0.15ef	8.07 ± 0.32d	18.26 ± 0.74ef	15.19 ± 0.71ef	4.90 ± 0.21d	8.02 ± 0.35cd	19.10 ± 0.83d	15.37 ± 0.67de
	T_5	3.81 ± 0.08efg	7.27 ± 0.16ef	15.94 ± 0.36hij	14.96 ± 0.30e-h	4.11 ± 0.14fg	7.83 ± 0.15e	17.64 ± 0.32gh	14.82 ± 0.30fgh	4.67 ± 0.09ef	7.94 ± 0.16cd	17.96 ± 0.36fg	14.90 ± 0.30fgh
	T_6	2.73 ± 0.12i	6.07 ± 0.25k	15.41 ± 0.57j-n	13.66 ± 0.53lmn	3.06 ± 0.09n	6.70 ± 0.23i	15.17 ± 0.58rs	14.03 ± 0.51k	3.81 ± 0.14k	7.18 ± 0.27h	15.77 ± 0.59kl	14.05 ± 0.53j
	T_7	3.73 ± 0.17fg	7.12 ± 0.31fg	16.38 ± 0.73fgh	14.14 ± 0.64i-l	3.93 ± 0.18hij	7.18 ± 0.31h	16.94 ± 0.71jkl	14.87 ± 0.61e-h	4.54 ± 0.20fg	7.64 ± 0.33ef	17.44 ± 0.76ghi	14.44 ± 0.63ij
	T_8	4.14 ± 0.15bc	8.00 ± 0.29b	18.03 ± 0.67c	15.26 ± 0.51e	4.37 ± 0.15bcd	8.27 ± 0.28cd	19.34 ± 0.82c	14.85 ± 0.29e-h	5.39 ± 0.17b	8.10 ± 0.28bc	19.97 ± 0.69c	14.79 ± 0.70f-i

Contd...

Variety & Treatment		2016-2017				2017-2018				2018-2019			
		Days after sowing (DAS)											
		25-40	40-55	55-70	70-85	25-40	40-55	55-70	70-85	25-40	40-55	55-70	70-85
V_3	T_0	2.01 ± 0.09k	5.48 ± 0.25l	14.37 ± 0.63o	13.65 ± 0.52klm	2.15 ± 0.07p	6.20 ± 0.22j	15.57 ± 0.58pqr	12.92 ± 0.55m	2.98 ± 0.12n	6.29 ± 0.25j	16.78 ± 0.68j	12.54 ± 0.51k
	T_1	2.94 ± 0.16hi	6.90 ± 0.34gh	14.96 ± 0.74mn	14.02 ± 0.65klm	3.43 ± 0.09l	7.33 ± 0.32gh	16.09 ± 0.70nop	14.16 ± 0.53jk	4.02 ± 0.18ij	7.30 ± 0.34gh	17.42 ± 0.81ghi	12.68 ± 0.38k
	T_2	3.61 ± 0.15g	6.92 ± 0.29gh	16.26 ± 0.64ghi	15.18 ± 0.55ef	3.86 ± 0.13ij	7.66 ± 0.26ef	17.10 ± 0.61ijk	14.61 ± 0.57g-j	4.61 ± 0.17fg	7.52 ± 0.28fg	17.90 ± 0.67fg	14.86 ± 0.56f-i
	T_3	3.70 ± 0.07fg	7.68 ± 0.14c	16.77 ± 0.30efg	15.20 ± 0.27ef	4.01 ± 0.12gh	7.85 ± 0.13e	17.56 ± 0.29ghi	15.29 ± 0.26de	4.92 ± 0.09d	7.46 ± 0.13fg	19.60 ± 0.34c	14.46 ± 0.25hij
	T_4	3.97 ± 0.15c-f	7.83 ± 0.29bc	19.36 ± 0.70b	17.98 ± 0.61a	4.45 ± 0.15b	8.43 ± 0.27bc	20.21 ± 0.67b	17.47 ± 0.62a	5.50 ± 0.19b	7.99 ± 0.28cd	20.73 ± 0.72b	17.67 ± 0.61a
	T_5	3.83 ± 0.21efg	7.63 ± 0.38cd	17.41 ± 0.91d	17.23 ± 0.79b	4.30 ± 0.12cde	7.83 ± 0.37e	18.55 ± 0.85de	16.02 ± 0.85c	5.12 ± 0.25c	7.53 ± 0.37fg	19.90 ± 0.80c	15.90 ± 0.69c
	T_6	3.18 ± 0.11h	6.97 ± 0.24gh	15.91 ± 0.53h-k	14.51 ± 0.45g-k	3.48 ± 0.08l	6.67 ± 0.22ef	16.76 ± 0.51klm	14.28 ± 0.46ijk	4.32 ± 0.14h	7.64 ± 0.24ef	17.71 ± 0.56fgh	14.52 ± 0.46ghi
	T_7	3.81 ± 0.18efg	7.12 ± 0.32fg	17.45 ± 0.78d	16.35 ± 0.68d	4.12 ± 0.13fg	7.49 ± 0.31fg	18.02 ± 0.76fg	15.63 ± 0.71cd	4.81 ± 0.21de	7.35 ± 0.32gh	19.06 ± 0.83d	15.88 ± 0.51c
	T_8	4.44 ± 0.19a	8.38 ± 0.35a	20.46 ± 0.88a	16.94 ± 0.67bc	4.68 ± 0.16a	8.64 ± 0.34ab	21.85 ± 0.95a	16.60 ± 0.49b	5.82 ± 0.21a	8.46 ± 0.34a	22.04 ± 0.83a	17.37 ± 0.66a
LS		**	**	**	**	**	**	**	**	**	**	**	**
CV %		4.03	1.79	1.95	2.02	2.05	1.77	1.73	1.68	2.01	1.64	1.67	1.66

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

4.4 Yield and yield contributing characters

4.4.1 Plant height

Except in 2017-2018, the height of wheat plants varied significantly due to varietal effect. In 2016-2017, the tallest plant (83.16 cm) was produced from V_3 and the lowest most (80.24 cm) recorded from V_1. Here the V_2 had the intermediate value (81.62 cm) regarding plant height in between V_3 and V_1. Like the first year (2016-2017), corresponding results were found in the last year (2018-2019) where the highest and lowest value represented as 86.88 and 84.42 cm from the variety V_3 and $V_{2,}$ respectively (Table 24).

With the significant variation, the treatment T_8 demonstrated the maximum and T_0 presented the minimum plant height among the treatments in the whole investigation period. Initially (2016-2017), treatment T_8 performed as the best (89.62 cm) plant height producer, while T_0 gave the least (75.76 cm). Rest of the treatments were influenced the plant height as descending order T_4 (87.19 cm) >T_5 (84.02 cm) >T_7 (82.08 cm) >T_3 (80.89 cm) >T_2 (79.35 cm) >T_6 (78.46 cm) >T_1 (77.61 cm) though T_3 and T_7 showed the statistical similarity. Result as like previous year, though T_8 and T_0 treatment activity showed greater (91.38 cm) and less (74.63 cm) plant height in 2017-2018, but had the same statistical interrelation among T_8 and $T_{4,}$ T_6 and T_2. A little bit increase was found in plant height compared with the previous year from the different soil amendments in 2018-2019. At this time, the maximum (93.81 cm) and minimum (78.45 cm) plant height noticed with T_8 and T_0, correspondingly (Table 25).

The Table 26 makes clear the varietal and treatment combination effect on the plant height under the investigation period from 2016-2017 to 2018-2019. The highest and the lowest plant height was obtained from V_3T_8 (95.20 cm) in 2018-2019 and V_1T_0 (74.21 cm) in 2017-2018 in that order.

4.4.2 Total plant/m^2

Statistical difference was noticed by variety regarding total plant/m^2 at harvest (Table 24). Among the varieties, V_3 exhibited the higher frequency of total plant/m^2 which was followed by V_1 and V_2 from the first year to last year in this research. In 2016-2017, the variety V_3 (182.22) and V_1 (177.00) showed parallel activity in terms of total plant/m^2

where V_2 had the second score (173.00). As cropping season 2016-2017, V_3 produced the maximum (187.67) total plant/m^2 having the statistical equality with V_1 (185.11), whereas V_2 (179.93) demonstrated the second highest during 2017-2018 (Table 24). The above trend of varietal performance was repeated in 2018-2019 with the greater plant/m^2 from V_3 (193.56) and lower plant/m^2 by V_1 (189.19).

Total plant/m^2 at harvest varied significantly due to different soil amendments all over the study period. The highest frequency of total plant/m^2 was found in T_8 (199.11) and the lowest result was recorded in T_0 (158.67) in 2016-2017 (Table 25). Where the next highest value was noticed from T_4 (191.56) and T_5 (185.00) had the statistical likeness. In the year 2017-2018, total plant/m^2 exhibited the matching trend due to various soil amendments as reported in 2016-2017. Where the highest (207.78) plant/m^2 produced by T_8 and had similar identity with the second most from T_4 (202.89). The lowest total plant/m^2 (163.89) was noticed in T_0 coupled with T_1 (170.22). Among the different soil amendments T_8 (216.11) performed superior results besides T_4 (209.89) to other treatments in 2018-2019. Rest of the treatments were showed also significant difference ranked as descending by T_5 (199.78), T_7 (190.22), T_3 (187.22), T_2 (179.00), T_6 (177.67) and T_1 (173.44), whereas the lowest one in T_0 (159.00).

Total plant/m^2 was not differed significantly due to interaction of variety and soil amendments during the whole period of the study. Although there was no significant variation among various aforesaid treatment combinations, numerical variations were observed from that combination. Here the maximum (225.00) and the minimum (153.00) values were recorded from the V_3T_8 and V_2T_0 in the 2018-2019 and 2016-2017 research period, respectively (Table 26).

4.4.3 Total tiller/plant

Considering the variety as a factor in this experiment, there was statistical significant deviation for total tiller/plant (Table 24). In 2016-2017, the highest total tiller/plant (3.11) was produced from V_3 and the loweest most (2.86) recorded from V_1. As previous year 2016-2017, V_3 produced the maximum total tiller/plant (3.19) and V_1 demonstrated minimum total tiller/plant (2.98) in the wheat growing period 2017-2018. The above trend of varietal performance was repeated in 2018-2019 with the greater and lower value of total tiller/plant from V_3 (3.51) and V_1 (3.15), correspondingly.

The rest of the treatments had also shown significant variations for total tiller/plant all over the study period. Though some treatments were acted as statistically similar, but the treatment T_8 and T_0 produced the maximum (3.67) and minimum (2.24) total tiller/plant, respectively in the period of 2016-2017. As a similar consequence on the number of total tiller/plant was reported in the year 2017-2018 compared to previous year. In this year, T_8 produced the highest total tiller/plant (3.80) and T_4 showed the second most total tiller/plant (3.62) but the least (2.32) in $T_{0.}$ During 2018-2019, treatment T_8 and T_0 furthermore demonstrated the greater (4.13) and the less (2.23) value of total tiller/plant (Table 25).

The number of total tiller/plant was insignificant at various combinations of varieties and treatments in all the three years of experiment. The above stated varieties and soil amendments showed great influence individually on total tiller/plant with mostly gradual increase. Although the interaction effect was insignificant but numerical values of this parameter greatly varied, where the maximum (4.40) and the minimum (2.27) number were obtained from V_3T_8 and V_2T_0 in 2018-2019 and in 2016-2017, correspondingly (Table 26).

4.4.4 Effective tiller/plant

The table 24 describes the significant variation among the selected varieties of wheat regarding effective tiller/plant from first year to third year on this study. A little bit difference was found among the varieties in the year of 2016-2017, where V_3 gave the maximum (2.93) and V_1 gave the minimum (2.71) value of effective tiller/plant. In the second year 2017-2018, varietal performance was presented as like previous year and had the greater value of effective tiller/plant from V_3 (3.06) and V_2 (2.92). In connection with the preceding year during the 2018-2019 cropping season, V_3 and V_2 also produced the highest (3.25) and lowest (2.98) number of effective tiller/plant with statistical identity in between V_2 (3.07) and V_1 (2.98).

Under this study, recorded results on effective tiller/plant showed significant difference by the influence of treatments. Out of different soil amendments, chemical fertilizer (T_8) and poultry manure (T_4) performed as superior to the rest of the treatments mainly unamend (T_0) all over the research period (Table 25). On the basis of the above statement, T_8 was produced the maximum number of effective tiller/plant (3.49) followed by T_4 (3.40), whereas the minimum value (2.07) was given by T_0 in 2016-2017. During 2017-2018, treatments were exhibited approximately equal performance with slight increase of effective tiller/plant. However, 3.64 and 2.10 were the greater and less value of effective tiller/plant obtained by treatment T_8 and $T_{0.}$ In the last year 2018-2019, the maximum value on this parameter was found from T_8 (3.89) and T_4 (3.69) and then gone downward as followed T_5 (3.36) >T_7 (3.22) >T_3 (3.09) >T_2 (2.91) >T_6 (2.84) >T_1 (2.73) over T_0 (2.16).

The attempts to evaluate the combined effects of variety and various soil amendments on effective tiller/plant had insignificant. But along the experimental period, as V_3 and T_8 individually presented the greater value thus their interaction (V_3T_8) produced the maximum effective tiller/plant (4.20) in 2018-2019 and oppositely minimum (1.87) effective tiller/plant noticed from V_2T_0 in 2016-2017 (Table 26).

Table 24: Effect of variety on yield and yield contributing characters of wheat.

Variety	Plant height (cm)			Total plant/m^2			Total tiller/plant			Effective tiller/plant		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	80.24 ± 1.07c	81.68 ± 1.19	84.42 ± 1.23c	177.00 ± 3.01b	185.11 ± 3.20a	189.19 ± 3.67b	2.86 ± 0.07c	2.95 ± 0.08c	3.16 ± 0.08c	2.71 ± 0.08b	2.81 ± 0.08c	2.98 ± 0.08b
V_2	81.62 ± 1.09b	82.48 ± 1.23	85.64 ± 1.33b	173.00 ± 2.78b	179.93 ± 2.80b	181.37 ± 3.06c	2.98 ± 0.10b	3.08 ± 0.10b	3.27 ± 0.11b	2.80 ± 0.10b	2.92 ± 0.10b	3.07 ± 0.11b
V_3	83.16 ± 1.14a	84.37 ± 1.18	86.88 ± 1.36a	182.22 ± 2.67a	187.67 ± 3.07a	193.56 ± 3.86a	3.11 ± 0.09a	3.19 ± 0.10a	3.52 ± 0.11a	2.93 ± 0.10a	3.06 ± 0.11a	3.25 ± 0.12a
LS	**	NS	**	**	**	**	**	**	**	**	**	**
CV (%)	1.77	5.42	1.50	5.21	4.20	3.27	5.03	6.02	5.83	6.37	6.56	5.92

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI-28, V_2 = BARI-29, V_3 = BARI-30, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

Table 25: Effect of organic and probiotic soil amendments on yield and yield contributing characters of wheat.

Treatment	Plant height (cm)			Total plant/m^2			Total tiller/plant			Effective tiller/plant		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
T_0	75.76 ± 1.05g	74.63 ± 1.05f	78.45 ± 1.46g	158.67 ± 3.11g	163.89 ± 2.59f	159.00 ± 2.29f	2.24 ± 0.07g	2.32 ± 0.04g	2.33 ± 0.07g	2.07 ± 0.08e	2.10 ± 0.06f	2.16 ± 0.07f
T_1	77.61 ± 1.31f	78.77 ± 1.38ef	81.43 ± 1.54f	164.89 ± 3.17fg	170.22 ± 2.17ef	173.44 ± 1.69e	2.62 ± 0.05f	2.73 ± 0.06f	2.98 ± 0.07f	2.47 ± 0.05d	2.58 ± 0.05e	2.73 ± 0.05e
T_2	79.35 ± 1.28e	80.57 ± 1.36de	83.44 ± 1.71e	171.44 ± 2.59ef	177.00 ± 3.09de	179.00 ± 2.35e	2.82 ± 0.06e	2.87 ± 0.06ef	3.11 ± 0.06ef	2.67 ± 0.07c	2.73 ± 0.06de	2.91 ± 0.05e
T_3	80.89 ± 1.46d	82.06 ± 1.28cde	85.63 ± 1.74d	175.44 ± 3.46de	182.22 ± 2.33cd	187.22 ± 2.20d	2.89 ± 0.06e	3.02 ± 0.05de	3.29 ± 0.07de	2.71 ± 0.05c	2.87 ± 0.06cd	3.09 ± 0.06d
T_4	87.19 ± 1.48b	88.68 ± 1.41ab	91.29 ± 1.92b	191.56 ± 2.86ab	202.89 ± 2.53a	209.89 ± 3.53b	3.51 ± 0.06b	3.62 ± 0.08b	3.84 ± 0.09b	3.40 ± 0.08a	3.53 ± 0.08a	3.69 ± 0.09b
T_5	84.08 ± 1.73c	85.63 ± 1.57bc	88.38 ± 1.94c	185.00 ± 3.44bc	193.78 ± 2.00b	199.78 ± 2.56c	3.24 ± 0.09c	3.33 ± 0.08c	3.62 ± 0.10c	3.07 ± 0.08b	3.18 ± 0.09b	3.36 ± 0.08c
T_6	78.46 ± 1.13ef	79.93 ± 1.61de	82.89 ± 1.50e	169.44 ± 2.74ef	173.67 ± 2.32e	177.67 ± 1.76e	2.76 ± 0.04ef	2.84 ± 0.07ef	3.13 ± 0.08ef	2.56 ± 0.06cd	2.71 ± 0.05de	2.84 ± 0.07e
T_7	82.08 ± 1.14d	83.92 ±1.29bcd	85.50 ± 1.78d	181.11 ± 2.69cd	186.67 ± 2.26bc	190.22 ± 2.66d	3.09 ± 0.07d	3.18 ± 0.07cd	3.40 ± 0.08d	2.91 ± 0.07b	3.05 ± 0.07bc	3.22 ± 0.07cd
T_8	89.62 ± 1.34a	91.38 ± 1.32a	93.81 ± 2.09a	199.11 ± 2.65a	207.78 ± 3.25a	216.11 ± 4.17a	3.67 ± 0.08a	3.80 ± 0.09a	4.13 ± 0.11a	3.49 ± 0.09a	3.64 ± 0.10a	3.89 ± 0.11a
LS	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	1.77	5.42	1.50	5.21	4.20	3.27	5.03	6.02	5.83	6.37	6.56	5.92

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

Table 26: Interaction effects of variety and soil amendments on yield and yield contributing characters of wheat.

Variety & Treatment		Plant height (cm)			Total plant/m^2			Total tiller/plant			Effective tiller/plant		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	T_0	75.12 ± 1.33	74.21 ± 2.08	77.00 ± 2.93	158.00 ± 7.23	161.33 ± 6.64	159.67 ± 4.33	2.27 ± 0.07	2.27 ± 0.07	2.33 ± 0.07	2.13 ± 0.18	2.07 ± 0.07	2.20 ± 0.12
	T_1	76.18 ± 2.46	77.88 ± 2.64	80.40 ± 2.97	164.00 ± 7.81	171.33 ± 4.47	175.00 ± 3.22	2.60 ± 0.12	2.67 ± 0.13	2.87 ± 0.07	2.40 ± 0.12	2.53 ± 0.07	2.67 ± 0.07
	T_2	77.97 ± 1.55	79.21 ± 2.37	82.90 ± 3.39	171.33 ± 5.55	177.33 ± 8.41	179.33 ± 6.01	2.73 ± 0.07	2.80 ±0.12	3.00 ± 0.12	2.53 ± 0.07	2.67 ± 0.13	2.87 ± 0.07
	T_3	79.40 ± 2.28	80.69 ± 2.48	84.70 ± 2.93	174.33 ± 6.12	183.00 ± 5.29	188.33 ± 1.76	2.80 ± 0.12	2.93 ± 0.07	3.20 ± 0.12	2.73 ± 0.13	2.80 ± 0.12	3.00 ± 0.12
	T_4	85.94 ± 2.91	87.27 ± 2.60	90.00 ± 3.33	190.67 ± 6.39	204.67 ± 2.60	212.33 ± 3.71	3.33 ± 0.07	3.47 ± 0.13	3.60 ± 0.12	3.20 ± 0.12	3.33 ± 0.07	3.47 ± 0.07
	T_5	82.13 ± 3.96	84.45 ± 3.77	86.40 ± 3.48	186.00 ± 6.43	194.00 ± 4.51	200.00 ± 1.53	3.00 ± 0.12	3.13 ± 0.07	3.33 ± 0.13	2.87 ± 0.07	2.93 ± 0.07	3.13 ± 0.07
	T_6	76.83 ± 2.01	78.61 ± 3.09	82.00 ± 2.97	168.33 ± 4.91	174.33 ± 4.41	177.67 ± 1.20	2.67 ± 0.07	2.73 ± 0.07	3.07 ± 0.13	2.47 ± 0.07	2.67 ± 0.07	2.80 ± 0.12
	T_7	80.96 ± 2.85	82.78 ± 3.12	83.78 ± 2.50	180.67 ± 5.78	189.33 ± 1.76	190.33 ± 4.33	2.93 ± 0.13	3.00 ± 0.12	3.20 ± 0.12	2.80 ± 0.12	2.87 ± 0.13	3.07 ± 0.07
	T_8	87.62 ± 2.73	89.99 ± 2.39	92.60 ± 3.12	199.67 ± 4.41	208.67 ± 6.64	220.00 ± 4.04	3.40 ± 0.12	3.53 ± 0.07	3.80 ± 0.12	3.27 ± 0.07	3.40 ± 0.12	3.60 ± 0.12
V_2	T_0	75.87 ± 2.42	74.55 ± 2.31	78.60 ± 2.70	156.33 ± 5.90	160.33 ± 2.03	153.00 ± 2.52	2.07 ± 0.07	2.20 ± 0.12	2.13 ± 0.07	1.87 ± 0.07	1.93 ± 0.07	2.00 ± 0.12
	T_1	77.71 ± 2.63	78.29 ± 2.83	81.69 ± 2.73	160.33 ± 5.24	166.00 ± 3.79	169.00 ± 2.31	2.67 ± 0.07	2.73 ± 0.07	2.93 ± 0.13	2.53 ± 0.07	2.60 ± 0.12	2.73 ± 0.07
	T_2	79.03 ± 2.84	80.06 ± 2.18	83.29 ± 3.17	167.00 ± 4.36	175.00 ± 5.13	176.67 ± 3.53	2.80 ± 0.12	2.87 ± 0.07	3.13 ± 0.07	2.67 ± 0.13	2.73 ± 0.07	2.93 ± 0.07
	T_3	80.38 ± 2.69	81.23 ± 2.05	85.48 ± 3.948	172.33 ± 8.95	178.33 ± 2.73	182.00 ± 3.46	2.87 ± 0.07	3.00 ± 0.12	3.27 ± 0.13	2.73 ± 0.07	2.87 ± 0.07	3.13 ± 0.07
	T_4	86.94 ± 2.51	88.47 ± 3.13	91.87 ± 4.01	188.00 ± 5.13	196.67 ± 3.48	199.00 ± 4.04	3.53 ± 0.07	3.67 ± 0.07	3.80 ± 0.12	3.40 ± 0.12	3.53 ± 0.07	3.67 ± 0.18
	T_5	84.70 ± 2.93	85.63 ± 2.79	88.62 ± 3.84	179.33 ± 7.54	191.00 ± 3.22	193.00 ± 3.51	3.33 ± 0.13	3.40 ± 0.12	3.60 ± 0.12	3.00 ± 0.12	3.20 ± 0.12	3.33 ± 0.07

Contd....

Variety & Treatment		Plant height (cm)			Total plant/m^2			Total tiller/plant			Effective tiller/plant		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
	T_6	78.50 ± 2.28	79.16 ± 3.77	83.12 ± 3.11	164.67 ± 4.06	170.33 ± 4.63	172.67 ± 2.73	2.73 ± 0.07	2.80 ± 0.12	3.00 ± 0.12	2.60 ± 0.12	2.67 ± 0.07	2.73 ± 0.07
	T_7	82.14 ± 1.85	83.87 ± 2.29	84.42 ± 3.81	176.00 ± 4.36	180.33 ± 4.06	183.67 ± 3.33	3.07 ± 0.07	3.20 ± 0.12	3.40 ± 0.12	2.87 ± 0.13	3.07 ± 0.07	3.20 ± 0.12
	T_8	89.29 ± 2.42	91.05 ± 2.77	93.63 ± 4.05	193.00 ± 4.04	201.33 ± 5.24	203.33 ± 4.33	3.73 ± 0.07	3.87 ± 0.13	4.20 ± 0.12	3.53 ± 0.13	3.67 ± 0.18	3.87 ± 0.18
	T_0	76.30 ± 2.27	75.13 ± 1.81	79.76 ± 2.76	161.67 ± 4.63	168.00 ± 4.16	164.33 ± 2.33	2.40 ± 0.12	2.27 ± 0.07	2.53 ± 0.07	2.20 ± 0.12	2.20 ± 0.12	2.27 ± 0.07
	T_1	78.95 ± 2.36	80.15 ± 2.54	82.20 ± 3.35	170.33 ± 2.60	173.33 ± 2.40	176.33 ± 1.86	2.60 ± 0.12	2.80 ± 0.12	3.13 ± 0.13	2.47 ± 0.07	2.60 ± 0.12	2.80 ± 0.12
	T_2	81.04 ± 2.58	82.44 ± 2.98	84.12 ± 3.64	176.00 ± 3.22	178.67 ± 3.71	181.00 ± 3.61	2.93 ± 0.13	2.93 ± 0.13	3.20 ± 0.12	2.80 ± 0.12	2.80 ± 0.12	2.93 ± 0.13
	T_3	82.90 ± 3.11	84.26 ± 2.38	86.70 ± 3.35	179.67 ± 3.38	185.33 ± 4.10	191.33 ± 4.49	3.00 ± 0.12	3.13 ± 0.07	3.40 ± 0.12	2.67 ± 0.07	2.93 ± 0.13	3.13 ± 0.13
V_3	T_4	88.67 ± 3.08	90.29 ± 2.20	92.00 ± 3.98	196.00 ± 3.79	207.33 ± 5.21	218.33 ± 4.63	3.67 ± 0.07	3.73 ± 0.18	4.13 ± 0.07	3.60 ±0.12	3.73 ± 0.18	3.93 ± 0.07
	T_5	85.42 ± 2.96	86.80 ± 2.49	90.13 ± 3.85	189.67 ± 4.10	196.33 ± 3.18	206.33 ± 4.41	3.40 ± 0.12	3.47 ± 0.13	3.93 ± 0.07	3.33 ± 0.07	3.40 ± 0.12	3.60 ± 0.12
	T_6	80.05 ± 1.87	82.02 ± 1.95	83.55 ± 2.80	175.33 ± 4.49	176.33 ± 3.76	182.67 ± 1.86	2.87 ± 0.07	3.00 ± 0.12	3.33 ± 0.13	2.60 ± 0.12	2.80 ± 0.12	3.00 ± 0.12
	T_7	83.13 ± 1.68	85.12 ± 1.94	88.29 ± 3.36	186.67 ± 2.33	190.33 ± 3.38	196.67 ± 3.53	3.27 ± 0.07	3.33 ± 0.07	3.60 ± 0.12	3.07 ± 0.07	3.20 ± 0.12	3.40 ± 0.12
	T_8	91.95 ± 1.85	93.09 ± 2.25	95.20 ± 4.75	204.67 ± 3.76	213.33 ± 4.33	225.00 ± 6.66	3.87 ± 0.07	4.00 ± 0.12	4.40 ± 0.12	3.67 ± 0.18	3.87 ± 0.18	4.20 ± 0.12
LS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)		1.77	5.42	1.50	5.21	4.20	3.27	5.03	6.02	5.83	6.37	6.56	5.92

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, CV = Co-efficient of variation.

4.4.5 Awn length

Variety responded significantly on awn length of wheat and almost alike development was reported by the variety in every year under the research period. The gradual increase in awn length of variety was noticed as descending order by V_3>V_1>V_2. Hence, V_3 (6.72 cm) and V_1 (6.61 cm) demonstrated the higher value with statistical identity of awn length compared to V_2 (6.41 cm) in 2016-2017. Such developments were continued in the second year (2017-2018) and third year (2018-2019) of the study and thus the maximum (6.86 cm) and the minimum (6.51 cm) length of awn recorded from V_3 and V_2 in 2018-2019 (Table 27).

A significant difference was found in the awn length of wheat among the various treatments in this study (Table 28). In 2016-2017, treatment T_8 performed well (7.15 cm) to produce awn length, while T_0 resulted in less (6.03 cm). Rest of the treatments were influenced the awn length by descending order as T_4 (6.95 cm) >T_5 (6.82 cm) >T_7 (6.66 cm) >T_3 (6.59 cm) >T_2 (6.40 cm) >T_6 (6.36 cm) >T_1 (6.03 cm), though $T_{8,}$ T_4 and T_5 had the statistical similarity. As like previous year, T_8 and T_0 treatment showed the highest (7.29 cm) and lowest (5.65 cm) awn length in 2017-2018. But statistical similarity was found among T_8 and $T_{4,}$ T_4 and T_5 treatments. Compared with the previous year, the awn length was increased in 2018-2019. Further, the maximum (7.38 cm) and minimum (5.36 cm) awn length was noticed from T_8 and T_0, respectively in this period (Table 28).

The insignificant interaction between variety and soil amendments was observed for awn length mostly with gradual increase. The numerical values of this parameter considering the maximum (7.50 cm) and the minimum (5.23 cm) length were obtained from V_3T_8 and V_2T_0 in 2018-2019 (Table 29).

4.4.6 Spike length

There were significant differences among the varieties in respect of spike length in the whole research period (Table 27). In 2017-2018, variety V_3 showed the largest spike length (7.89 cm) which had similar statistical equality with V_1 (7.85 cm), the least spike length was observed in V_2 (7.63 cm). Similar results were noticed by the varieties in 2017-2018, at this time V_3 also produced the higher spike length (8.00 cm) followed by V_1 (7.98 cm) and V_2 (7.85 cm). In the last year of study, each variety showed a slight increase in spike length compared to previous year. But statistical identity was found between V_3 (8.10 cm) and V_1 (7.98 cm).

There were significant differences among the sources soil amendment in terms of spike length in every year of the study (Table 28). Chemical fertilizer (T_8) was resulted the largest spike length than other soil amendments. Among the organic soil amendments, poultry manure produced larger spike length. During 2016-2017, T_8 demonstrated the highest (8.60 cm) spike length statistically at par with T_4 (8.12 cm), while the smallest spike length reported from T_0 (7.31 cm). In contrast, in 2017-2018, similar effects were recorded from the treatments where the largest (8.41 cm) and the smallest (7.12 cm) spike length were also recorded from T_8 and T_0, correspondingly. There the application of poultry manure (8.29 cm) was comparable with chemical fertilizer (8.41 cm) in respect of this parameter. The spike length for all the treatments involving soil amendment was marginally higher in 2018-2019 than previous years. At this point, poultry manure (T_4) was revealed the second most ranked next to chemical fertilizer (T_8) having the values (8.43 cm) and (8.60 cm), respectively (Table 28).

There was no significant variation among the treatment combinations on spike length of wheat in the complete study period. The lengths of spike were ranged as the lowest and the highest from 6.89 to 8.73 cm in research time and that were presented by V_2T_0 and V_3T_8 in 2018-2019 (Table 29).

4.4.7 Spikelet/spike

Spikelet/spike was significantly affected by the selected varieties of wheat under this experiment period. The maximum value (16.34) of this parameter was observed with V_3 and lowers one by V_2 (15.75). However, performance of V_3 was closely followed by V_1 (16.04) on this parameter in 2016-2017. Statistically significant difference was found among the varieties in 2017-2018. Where V_3 was produced higher number (16.52) spikelet/spike followed by V_1 (16.17), but V_1 was statistically at par with V_2 (16.03). Similar performance of wheat variety was noticed in this regard during 2018-2019.

As also previous, V_3 was produced the highest (16.67) spikelet/spike, while V_1 and V_2 were presented the next values 16.36 and 16.20 with no significant differences between two varieties (Table 27).

Application of different soil amendments influenced spikelet/spike significantly in each year of the study. From the recorded result in the table 28, it is noticed that spikelet/spike varied significantly from 13.80 (T_0) to 17.97 (T_8) and this was also the maximum and the minimum value for this parameter under the study time. But among the treatments, the same statistical interrelation was observed as with (i) T_8 and $T_{4,}$ (ii) $T_{5,}$ T_7 and $T_{3,}$ (iii) $T_{6,}$ T_2 and T_1 all over the experimental period.

There was no significant variation among the treatment combinations of variety and soil amendments concerning the spikelet/spike at harvesting from the first year to the last year of the study. Nevertheless, the upper limit spikelet/spike (18.20) was recorded from the treatment combination $V_3T_{8,}$ while the lower limit of spikelet/spike (13.56) was obtained from the treatment combination V_2T_0 (Table 29).

4.4.8 Fertile spikelet/spike

In the present experiment, varietal effect on fertile spikelet/spike showed significant difference in each year. The fertile spikelet/spike under variety V_3 was higher compared to V_1 and V_2 in the whole research period. In 2016-2017, the better fertile spikelet/spike (15.78) was observed with V_3 followed by V_1 (15.48) and V_2 (15.19). As compared to the first year, a little bit improvement of fertile spikelet/spike was recorded in the second and the third year of investigation. Thus, among the varieties V_3 produced the maximum (16.06) fertile spikelet/spike during 2018-2019, while the minimum value (15.19) was found from V_2 in 2016-2017 (Table 27).

Data shows in Table 28 indicated that fertile spikelet/spike of wheat was positively enhanced by various soil amendments at all round the research. Further, data demonstrated that incorporation of chemical fertilizer (T_8) and poultry manure (T_4) was at par to each other with superior significance over the rest of the treatments. However, in 2016-2017, the maximum (16.89) and the minimum (14.00) result yielded on this parameter from T_8 and T_0.

Further evaluation showed that probiotics acted as the third most significant transporter of the fertile spikelet/spike. Related records were also reported for this parameter during 2017-2018 and 2018-2019. Although the parallel trend of fertile spikelet/spike from respective treatments recorded, but 17.24 were the biggest figure and 13.22 was the lowest one obtained from T_8 and T_0 during 2018-2019 (Table 28).

Data shows in Table 29 indicated that there was no significant difference among variety and various treatment combinations in terms of their effect on fertile spikelet/spike over the study period. Overall, 4.20 was the high-grade result on the contrary, 1.87 was the low-grade result for fertile spikelet/spike under the experimental treatment combinations V_3T_8 and V_2T_0 in 2018-2019 and 2017-2018, respectively.

Table 27: Effect of variety on yield and yield contributing characters of wheat.

Variety	Awn length (cm)			Spike length (cm)			Spikelet/spike			Fertile spikelet/spike		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	6.61 ± 0.08a	6.69 ± 0.09b	6.76 ± 0.11b	7.75 ± 0.08ab	7.853 ± 0.09ab	7.98 ± 0.10ab	16.04 ± 0.18b	16.17 ± 0.22b	16.36 ± 0.24b	15.48 ± 0.18b	15.66 ± 0.19b	15.77 ± 0.25b
V_2	6.41 ± 0.07b	6.53 ± 0.10c	6.62 ± 0.11c	7.63 ± 0.09b	7.76 ± 0.09b	7.85 ± 0.10b	15.75 ± 0.17c	16.03 ± 0.23b	16.20 ± 0.25b	15.19 ± 0.19c	15.31 ± 0.21c	15.47 ± 0.23c
V_3	6.72 ± 0.08a	6.80 ± 0.10a	6.86 ± 0.12a	7.89 ± 0.08a	8.00 ± 0.09a	8.10 ± 0.09a	16.34 ± 0.18a	16.52 ± 0.22a	16.67 ± 0.24a	15.78 ± 0.18a	15.92 ± 0.18a	16.06 ± 0.22a
LS	**	**	**	*	*	**	**	**	**	**	**	**
CV (%)	3.46	3.07	2.15	4.58	4.03	2.93	2.76	3.23	3.23	2.42	2.00	2.61

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI-28, V_2 = BARI-29, V_3 = BARI-30, DAS = Days after sowing, LS = Level of significance, ** = 1% Level of significance, * = 5% Level of significance, CV = Co-efficient of variation.

Table 28: Effect of organic and probiotic soil amendments on yield and yield contributing characters of wheat.

Treatment	Awn length (cm)			Spike length (cm)			Spikelet/spike			Fertile spikelet/spike		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
T_0	6.03 ± 0.07g	5.65 ± 0.09g	5.36 ± 0.05f	7.31 ± 0.16e	7.12 ± 0.10f	7.00 ± 0.05e	14.66 ± 0.21d	14.20 ± 0.20d	13.80 ± 0.15d	14.00 ± 0.20g	13.78 ± 0.17f	13.22 ± 0.19f
T_1	6.26 ± 0.09f	6.37 ± 0.08f	6.50 ± 0.06e	7.45 ± 0.11de	7.55 ± 0.11e	7.63 ± 0.08d	15.33 ± 0.14c	15.50 ± 0.26c	15.77 ± 0.17c	14.74 ± 0.22f	14.86 ± 0.13e	15.08 ± 0.22e
T_2	6.40 ± 0.09ef	6.54 ± 0.07ef	6.63 ± 0.07e	7.62 ± 0.12de	7.73 ± 0.11de	7.84 ± 0.08d	15.60 ± 0.12c	15.86 ± 0.20c	16.10 ± 0.14c	15.20 ± 0.12de	15.32 ± 0.10d	15.51 ± 0.13d
T_3	6.59 ± 0.09de	6.71 ± 0.07de	6.82 ± 0.08d	7.77 ± 0.09bcd	7.99 ± 0.12bcd	8.18 ± 0.10c	16.10 ± 0.14b	16.40 ± 0.23b	16.63 ± 0.16b	15.50 ± 0.14cd	15.72 ± 0.12c	15.93 ± 0.08c
T_4	6.95 ± 0.09ab	7.17 ± 0.05ab	7.27 ± 0.07a	8.12 ± 0.12ab	8.29 ± 0.11ab	8.43 ± 0.08ab	17.16 ± 0.13a	17.59 ± 0.17a	17.81 ± 0.16a	16.60 ± 0.16a	16.78 ± 0.09a	17.00 ± 0.13a
T_5	6.82 ± 0.07bc	6.99 ± 0.09bc	7.12 ± 0.06b	7.91 ± 0.10bc	8.12 ± 0.07abc	8.25 ± 0.06bc	16.43 ± 0.14b	16.68 ± 0.16b	16.88 ± 0.21b	15.90 ± 0.16b	16.16 ± 0.15b	16.40 ± 0.17b
T_6	6.36 ± 0.10f	6.53 ± 0.06ef	6.62 ± 0.07e	7.54 ± 0.10cde	7.66 ± 0.08de	7.77 ± 0.08d	15.51 ± 0.15c	15.78 ± 0.20c	16.01 ± 0.17c	14.90 ± 0.18ef	15.10 ± 0.17de	15.41 ± 0.15de
T_7	6.66 ± 0.06cd	6.83 ± 0.07cd	6.97 ± 0.06c	7.79 ± 0.12bcd	7.95 ± 0.09cd	8.08 ± 0.06c	16.26 ± 0.19b	16.46 ± 0.11b	16.70 ± 0.19b	15.62 ± 0.15bc	15.89 ± 0.13bc	16.12 ± 0.16bc
T_8	7.15 ± 0.06a	7.29 ± 0.06a	7.38 ± 0.07a	8.27 ± 0.08a	8.41 ± 0.09a	8.60 ± 0.10a	17.36 ± 0.17a	17.68 ± 0.16a	17.97 ± 0.17a	16.89 ± 0.13a	17.06 ± 0.10a	17.24 ± 0.18a
LS	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	3.46	3.07	2.15	4.58	4.03	2.93	2.76	3.23	3.23	2.42	2.00	2.61

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

Table 29: Interaction effects of variety and soil amendments on yield and yield contributing characters of wheat.

Variety & Treatment		Awn length (cm)			Spike length (cm)			Spikelet/spike			Fertile spikelet/spike		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	T_0	6.04 ± 0.14	5.69 ± 0.05	5.39 ± 0.07	7.29 ± 0.18	7.13 ± 0.13	7.00 ± 0.07	15.00 ± 0.42	14.27 ± 0.50	13.87 ± 0.24	14.20 ± 0.35	14.00 ± 0.21	13.17 ± 0.46
	T_1	6.28 ± 0.19	6.38 ± 0.16	6.50 ± 0.09	7.42 ± 0.22	7.51 ± 0.19	7.63 ± 0.11	15.30 ± 0.21	15.47 ± 0.39	15.70 ± 0.36	14.67 ± 0.33	14.77 ± 0.09	14.93 ± 0.41
	T_2	6.47 ± 0.20	6.59 ± 0.14	6.66 ± 0.14	7.59 ± 0.17	7.71 ± 0.11	7.85 ± 0.10	15.53 ± 0.18	15.83 ± 0.27	16.07 ± 0.12	15.13 ± 0.07	15.27 ± 0.13	15.47 ± 0.27
	T_3	6.63 ± 0.15	6.71 ± 0.12	6.81 ± 0.13	7.76 ± 0.11	8.00 ± 0.12	8.20 ± 0.21	16.00 ± 0.12	16.30 ± 0.27	16.53 ± 0.24	15.40 ± 0.27	15.70 ± 0.17	15.87 ± 0.15
	T_4	6.96 ± 0.15	7.15 ± 0.07	7.26 ± 0.09	8.15 ± 0.13	8.29 ± 0.17	8.45 ± 0.23	17.20 ± 0.23	17.53 ± 0.48	17.83 ± 0.26	16.60 ± 0.27	16.80 ± 0.06	17.03 ± 0.20
	T_5	6.85 ± 0.09	7.01 ± 0.08	7.15 ± 0.09	7.90 ± 0.11	8.12 ± 0.12	8.25 ± 0.13	16.33 ± 0.35	16.50 ± 0.29	16.77 ± 0.38	15.93 ± 0.24	16.33 ± 0.18	16.60 ± 0.23
	T_6	6.41 ± 0.19	6.52 ± 0.14	6.63 ± 0.13	7.49 ± 0.27	7.56 ± 0.12	7.75 ± 0.10	15.47 ± 0.26	15.67 ± 0.24	15.90 ± 0.21	14.83 ± 0.22	15.03 ± 0.19	15.30 ± 0.25
	T_7	6.67 ± 0.08	6.87 ± 0.09	7.03 ± 0.09	7.80 ± 0.18	7.95 ± 0.18	8.09 ± 0.04	16.13 ± 0.49	16.23 ± 0.18	16.57 ± 0.43	15.63 ± 0.19	15.97 ± 0.15	16.30 ± 0.15
	T_8	7.16 ± 0.11	7.29 ± 0.09	7.39 ± 0.11	8.32 ± 0.06	8.40 ± 0.23	8.59 ± 0.26	17.40 ± 0.27	17.70 ± 0.32	17.97 ± 0.29	16.93 ± 0.35	17.07 ± 0.12	17.27 ± 0.37
V_2	T_0	5.90 ± 0.12	5.49 ± 0.23	5.23 ± 0.08	7.20 ± 0.37	7.02 ± 0.19	6.89 ± 0.06	14.30 ± 0.44	13.97 ± 0.26	13.53 ± 0.29	13.47 ± 0.29	13.20 ± 0.15	12.97 ± 0.09
	T_1	6.11 ± 0.06	6.25 ± 0.14	6.39 ± 0.09	7.35 ± 0.12	7.43 ± 0.19	7.48 ± 0.18	15.00 ± 0.12	15.20 ± 0.42	15.47 ± 0.29	14.50 ± 0.27	14.57 ± 0.22	14.73 ± 0.43
	T_2	6.19 ±0.09	6.42 ± 0.10	6.50 ± 0.10	7.53 ± 0.28	7.65 ± 0.28	7.70 ± 0.22	15.33 ± 0.12	15.53 ± 0.35	15.87 ± 0.18	15.10 ± 0.06	15.10 ± 0.15	15.30 ± 0.21
	T_3	6.35 ± 0.09	6.55 ± 0.13	6.72 ± 0.13	7.67 ± 0.24	7.86 ± 0.24	8.07 ± 0.20	15.83 ± 0.15	16.10 ± 0.59	16.40 ± 0.31	15.30 ± 0.15	15.53 ± 0.24	15.80 ± 0.12
	T_4	6.80 ± 0.23	7.05 ± 0.10	7.13 ± 0.140	7.95 ± 0.30	8.17 ± 0.24	8.31 ± 0.06	16.80 ± 0.12	17.43 ± 0.23	17.60 ± 0.38	16.37 ± 0.41	16.53 ± 0.12	16.73 ± 0.18
	T_5	6.66 ± 0.09	6.85 ± 0.26	7.00 ± 0.12	7.78 ± 0.22	8.03 ± 0.09	8.15 ± 0.09	16.23 ± 0.15	16.67 ± 0.24	16.80 ± 0.32	15.50 ± 0.21	15.67 ± 0.18	15.83 ± 0.09
	T_6	6.13 ± 0.08	6.41 ± 0.05	6.52 ± 0.14	7.45 ± 0.07	7.58 ± 0.16	7.63 ± 0.15	15.17 ± 0.15	15.50 ± 0.29	15.73 ± 0.29	14.57 ± 0.22	14.80 ± 0.35	15.13 ± 0.26
	T_7	6.54 ± 0.10	6.62 ± 0.12	6.79 ± 0.07	7.61 ± 0.26	7.79 ± 0.13	7.93 ± 0.13	16.07 ± 0.23	16.43 ± 0.15	16.67 ± 0.33	15.23 ± 0.15	15.47 ± 0.12	15.67 ± 0.23
	T_8	7.00 ± 0.07	7.16 ± 0.11	7.25 ± 0.08	8.12 ± 0.19	8.28 ± 0.08	8.47 ± 0.13	17.03 ± 0.24	17.40 ± 0.31	17.73 ± 0.41	16.70 ± 0.17	16.90 ± 0.21	17.10 ± 0.27

Contd...

Variety & Treatment		Awn length (cm)			Spike length (cm)			Spikelet/spike			Fertile spikelet/spike		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_3	T_0	6.15 ± 0.09	5.78 ± 0.13	5.47 ± 0.09	7.45 ± 0.34	7.20 ± 0.26	7.13 ± 0.06	14.67 ± 0.24	14.37 ± 0.32	14.00 ± 0.23	14.33 ± 0.19	14.13 ± 0.19	13.53 ± 0.34
	T_1	6.40 ± 0.19	6.49 ± 0.10	6.60 ± 0.13	7.58 ± 0.24	7.72 ± 0.23	7.79 ± 0.11	15.70 ± 0.21	15.83 ± 0.60	16.13 ± 0.19	15.07 ± 0.58	15.23 ± 0.20	15.57 ± 0.23
	T_2	6.52 ± 0.11	6.59 ± 0.12	6.75 ± 0.14	7.73 ± 0.21	7.84 ± 0.22	7.97 ± 0.10	15.93 ± 0.18	16.20 ± 0.44	16.37 ± 0.35	15.37 ± 0.38	15.60 ± 0.12	15.77 ± 0.17
	T_3	6.79 ± 0.16	6.86 ± 0.03	6.94 ± 0.16	7.88 ± 0.14	8.11 ± 0.27	8.27 ± 0.15	16.47 ± 0.29	16.80 ± 0.31	16.97 ± 0.23	15.80 ± 0.25	15.93 ± 0.18	16.13 ± 0.09
	T_4	7.10 ± 0.06	7.31 ± 0.05	7.43 ± 0.09	8.25 ± 0.16	8.40 ± 0.20	8.52 ± 0.08	17.47 ± 0.18	17.80 ± 0.17	18.00 ± 0.27	16.83 ± 0.15	17.00 ± 0.12	17.23 ± 0.27
	T_5	6.94 ± 0.13	7.13 ± 0.08	7.22 ± 0.05	8.05 ± 0.21	8.20 ± 0.14	8.33 ± 0.08	16.73 ± 0.18	16.87 ± 0.35	17.07 ± 0.48	16.27 ± 0.24	16.47 ± 0.18	16.77 ± 0.15
	T_6	6.53 ± 0.18	6.66 ± 0.09	6.72 ± 0.13	7.67 ± 0.18	7.85 ± 0.10	7.94 ± 0.11	15.90 ± 0.21	16.17 ± 0.44	16.40 ± 0.32	15.30 ± 0.38	15.47 ± 0.30	15.80 ± 0.12
	T_7	6.78 ± 0.13	6.99 ± 0.08	7.10 ± 0.06	7.96 ± 0.22	8.12 ± 0.12	8.21 ± 0.06	16.57 ± 0.23	16.70 ± 0.17	16.87 ± 0.35	16.00 ± 0.25	16.23 ± 0.15	16.40 ± 0.29
	T_8	7.28 ± 0.04	7.42 ± 0.07	7.50 ± 0.14	8.39 ± 0.13	8.55 ± 0.13	8.73 ± 0.10	17.63 ± 0.35	17.93 ± 0.20	18.20 ± 0.21	17.03 ± 0.15	17.20 ± 0.21	17.37 ± 0.38
LS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)		3.46	3.07	2.15	4.58	4.03	2.93	2.76	3.23	3.23	2.42	2.00	2.61

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, CV = Co-efficient of variation.

4.4.9 Grains/spike

A significant variation in grains/spike of wheat was noticed due to varietal influences appearing in the study length. In 2016-2017, the grains/spike varied from 39.81 to 38.56 that were presented by V_3 and $V_{2.}$ In the next two years of experiment, V_3 also demonstrated higher efficiency than the other two varieties. Thus with the related performance of the varieties in 2018-2019, V_3 marked as the best producer of grains/spike (42.14), whereas in 2017-2018 V_2 reported as the lower producer with the value of 39.70 (Table 30).

In comparison to the control plot, development of grains/spike was significantly higher under different treatment combinations round the research. The maximum number of grains/spike (42.74) was noted in T_8 and the minimum value (36.88) obtained by T_0 in 2016-2017. There the treatments were ranked in order $T_8>T_4>T_5>T_7>T_3>T_6>T_2>T_1>T_0$ for grains/spike production. The grain in each spike was also varied with different soil amendments in 2017-2018. Where T_8 was produced the utmost grains/spike (44.41) which had statistical equality with T_4 (43.50) and the least value recorded from T_0 (35.04). In 2018-2019, the grains/spike was affected greatly by T_8 with the best value 45.73, oppositely 33.67 was the poorest value observed from T_0 (Table 31).

Treatment combination effects did not vary significantly for grains/spike except in 2018-2019. With statistical variation V_3T_8 combination was reported the highest number of grains/spike (47.60) followed by V_3T_4 (46.00) and the combination V_2T_0 (33.20) was noted as the lower one during 2018-2019 (Table 32).

4.4.10 Deformed grains/spike

In the three years of the study, nearly equal number of deformed grains/spike was produced by the selected wheat varieties with significant deviation. In 2016-2017, the higher (2.90) and the lower number (2.70) of deformed grains/spike recorded from V_1 and V_2, respectively. In the next two years, alike results were found in respect of deformed grains/spike, where 2.90 was the maximum and 2.65 was the minimum value for recorded by V_1 and V_2 in 2018-2019 (Table 30).

The number of deformed grains/spike varied significantly by the treatment factor all over the experimental duration. Most of the soil amendments exhibited a similar trend in production of deformed grains/spike. Through the control treatment (T_0) was denoted the highest score followed by T_8, but the lowest was found in T_5 followed by T_7 in each year. The chronological higher values of the deformed grains/spike were recorded by T_0 (3.36, 3.49 and 3.72) and lower in T_5 (2.38, 2.29 and 2.27) collected in the sequential year of 2016-2017, 2017-2018 and 2018-2019, respectively (Table 31). The deformed grains/spike did not influence significantly by the interaction of variety coupled with soil amendments in the study period. But numerical differences were recorded from the treatment combinations where V_1T_0 (4.00) and V_2T_5 (2.17) in 2018-2019 (Table 32).

4.4.11 Grain weight/spike

The significant variation of grain weight/spike was recorded by the varietal influence in each sampling year. The grain weight/spike was ranged from 1.80-1.89 g in 2016-2017, where the maximum weight was observed by V_3 (1.89 g) which was at par with V_1 (1.86 g) and the minimum (1.80 g) was noted at V_2. There was statistical equality among the varieties in the rest years of the experiment. Between the last two years, 2018-2019 had demonstrated a slight increase of grain weight/spike over 2017-2018. So, comparatively the higher (2.02 g) and the lower (1.85 g) grain weight/spike were recorded by V_3 and V_2 (Table 30).

Grain weight/spike at harvest varied significantly due to different soil amendments during the study period (Table 31). The highest value of grain weight/spike was found in T_8 (2.07 g) and the minimum result was recorded by T_0 (1.66 g) in 2016-2017. Where the next highest value was noticed from T_4 (1.98 g) and T_5 (1.93 g) had the statistical likeness. In the year 2017-2018, grain weight/spike exhibited a similar trend reported in 2016-2017. There the highest (2.15 g) grain weight/spike produced by T_8 and the second most in T_4 (2.10 g), but the lowest grain weight/spike (1.62 g) was noticed in T_0. Among the different soil amendments, T_8 (2.20 g) was performed superior besides T_4 (2.14 g) to other treatments in 2018-2019. Rest of the treatments were showed also significant difference ranked as descending by T_5 (2.06 g), T_7 (2.01 g), T_3 (1.99 g), T_2 (1.93 g), T_6 (1.89 g), T_1 (1.86 g), while the lowest one in T_0 (1.60 g).

The objective to evaluate the combined effects of variety and various soil amendments on grain weight/spike was insignificant in 2016-2017 and in 2017-2018, while significant results were found in 2018-2019. In the experimental period 2018-2019, as V_3 and T_8 individually presented the greater value on this parameter thus their interaction (V_3T_8) produced the maximum grain weight/spike (2.25 g) and oppositely the minimum (1.57 g) grain weight/spike noticed from V_2T_0 in the same period. Furthermore, data in Table 32 clearly demonstrated the next greater grain weight/spike by V_1T_8 (2.20 g) with statistical akin by V_3T_4 (2.18 g).

4.4.12 1000-grain weight

The response of 1000-grain weight of selected wheat varieties in the research period is shown in the table 30. There this factor was significant in 2016-2017 and 2018-2018 other than 2017-2018. A bit increase in 1000-grain weight was reported in the consecutive years of the experiment. In 2016-2017, the maximum 1000-grain weight (51.86 g) was noticed in V_3 at the same time the minimum value (51.06 g) of 1000-grain weight obtained from V_3. Though not significant differences were observed for 1000-grain weight during 2017-2018, but the trend of increase was parallel with the previous year. Here V_3 was superior (52.22 g), while V_2 had the minimum (51.72 g) weight in respect of 1000-seed of wheat. At the end year (2018-2019) of the experiment, significantly higher (52.52 g) and lower (51.89 g) 1000-grain weight was obtained from V_3 and V_2, respectively.

The reaction of 1000-grain weight of wheat to different soil amendments showed significantly positive results in every year (Table 31). In 2016-2017, wheat plants that received chemical fertilizer (T_8) had the highest 1000-grain weight (53.28 g) followed by poultry manure (T_4), while plants in the control plot had the lowest 1000-grain weight (49.52 g). In 2017-2018, 1000-grain weight differed significantly under various treatments. In this case, 1000-grain weight was also higher (53.81 g) under T_8, but statistically interlinked with T_4 (53.51 g), T_5 (52.98 g), T_7 (52.51 g) and T_3 (52.34 g), while T_0 had the lower mean of 1000-grain weight (48.61 g). During 2018-2019, chemical fertilizer (T_8) was superior with a mean of 1000-grain weight (54.12 g), while the plants that did not receive any soil amendments (T_0) had the lowest mean (48.78 g).

Experimental results revealed that there were not significant differences among treatment combinations during 2016-2017 and 2017-2018, but there was significant variation in 2018-2019 with regard to 1000-grain weight (Table 32). Although the first and the second year were presented not statistical variation among the treatments, but numerically the leading 1000-grain weight (54.02 g) was recorded from V_3T_8, whereas the inferior (48.55 g) was noticed in V_1T_0. The value 54.45 g was remarked as the utmost, while the value 48.21 g denoted as the lowest exhibited by V_3T_8 and V_1T_0, correspondingly during 2018-2019. At the same time, V_1T_8 was demonstrated the second higher 1000-grain weight (54.21 g) and this was statistically similar with V_3T_4 (54.14 g) and V_1T_4 (54.03 g).

Table 30: Effect of variety on yield and yield contributing characters of wheat.

Variety	Grains/spike			Deformed grains/spike			Grain weight/spike (g)			1000-grain weight (g)		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	39.19 ± 0.40b	40.06 ± 0.52b	41.19 ± 0.83b	2.90 ± 0.08a	2.89 ± 0.09a	2.90 ± 0.11a	1.86 ± 0.03a	1.94 ± 0.03b	1.99 ± 0.04b	51.56 ± 0.32ab	52.07 ± 0.37	52.25 ± 0.38b
V_2	38.56 ± 0.37c	39.70 ± 0.51b	40.62 ± 0.81c	2.71 ± 0.07b	2.66 ± 0.08c	2.65 ± 0.09c	1.80 ± 0.03b	1.85 ± 0.03c	1.89 ± 0.04c	51.06 ± 0.26b	51.72 ± 0.46	51.89 ± 0.36c
V_3	39.81 ± 0.48a	41.04 ± 0.63a	42.14 ± 0.90a	2.83 ± 0.07a	2.80 ± 0.08b	2.79 ± 0.10b	1.89 ± 0.03a	1.97 ± 0.03a	2.02 ± 0.04a	51.86 ± 0.28a	52.22 ± 0.34	52.52 ± 0.35a
LS	**	**	**	**	**	**	**	**	**	*	NS	**
CV (%)	1.52	2.55	1.09	6.12	5.85	4.80	3.69	2.90	1.48	1.90	3.12	1.23

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI-28, V_2 = BARI-29, V_3 = BARI-30, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, ** = 1% Level of significance, * = 5% Level of significance, CV = Co-efficient of variation.

Table 31: Effect of organic and probiotic soil amendments on yield and yield contributing characters of wheat.

Treatment	Grains/spike			Deformed grains/spike			Grain weight/spike (g)			1000-grain weight (g)		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
T_0	36.88 ± 0.30f	35.04 ± 0.30e	33.67 ± 0.87i	3.36 ± 0.07a	3.49 ± 0.07a	3.72 ± 0.09a	1.66 ± 0.03g	1.62 ± 0.02g	1.60 ± 0.04g	49.52 ± 0.44f	48.61 ± 0.51e	48.78 ± 0.41i
T_1	36.98 ± 0.22f	38.42 ± 0.23d	39.53 ± 0.88h	2.80 ± 0.07c	2.69 ± 0.07c	2.63 ± 0.05d	1.74 ± 0.02f	1.80 ± 0.03f	1.86 ± 0.04f	50.03 ± 0.37f	51.05 ± 0.30d	51.30 ± 0.31h
T_2	38.11 ± 0.21e	39.36 ± 0.26d	40.67 ± 0.96f	2.67 ± 0.06cd	2.62 ± 0.06c	2.56 ± 0.05d	1.80 ± 0.03ef	1.88 ± 0.03de	1.93 ± 0.05e	51.19 ± 0.33de	51.84 ± 0.59bcd	51.95 ± 0.33f
T_3	38.76 ± 0.21d	40.51 ± 0.39c	41.58 ± 1.02e	2.52 ± 0.07de	2.47 ± 0.06d	2.42 ± 0.06e	1.83 ± 0.02de	1.91 ± 0.03d	1.99 ± 0.04d	51.77 ± 0.19cd	52.34 ±0.34a-d	52.49 ± 0.34e
T_4	42.11 ± 0.40b	43.50 ± 0.59a	44.80 ± 1.13b	3.14 ± 0.05b	3.07 ± 0.06b	2.94 ± 0.04c	1.98 ± 0.02b	2.10 ± 0.02b	2.14 ± 0.05b	52.94 ± 0.27ab	53.51 ± 0.47ab	53.90 ± 0.39b
T_5	40.17 ± 0.22c	41.59 ± 0.43b	43.14 ± 1.08c	2.38 ± 0.04e	2.29 ± 0.05e	2.27 ± 0.05f	1.93 ± 0.03bc	2.02 ± 0.02c	2.06 ± 0.05c	52.27 ± 0.21bc	52.98 ± 0.90abc	53.19 ± 0.38c
T_6	37.20 ± 0.20f	38.71 ± 0.27d	40.23 ± 0.97g	2.73 ± 0.07c	2.66 ± 0.07c	2.57 ± 0.06d	1.77 ± 0.03ef	1.84 ± 0.03ef	1.89 ± 0.05f	50.48 ± 0.40ef	51.39 ± 0.31cd	51.60 ± 0.34g
T_7	39.73 ± 0.25c	40.83 ± 0.42bc	42.50 ± 1.07d	2.47 ± 0.04e	2.38 ± 0.06de	2.34 ± 0.03ef	1.89 ± 0.02cd	1.99 ± 0.02c	2.01 ± 0.05d	51.97 ± 0.14bcd	52.51 ± 0.26a-d	52.64 ± 0.36d
T_8	42.74 ± 0.37a	44.41 ± 0.53a	45.73 ± 1.04a	3.23 ± 0.06a	3.37 ± 0.06a	3.53 ± 0.06b	2.07 ± 0.03a	2.15 ± 0.03a	2.20 ± 0.05a	53.28 ± 0.30a	53.81 ± 0.29a	54.12 ± 0.40a
LS	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	1.52	2.55	1.09	6.12	5.85	4.80	3.69	2.90	1.48	1.90	3.12	1.23

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

Table 32: Interaction effects of variety and soil amendments on yield and yield contributing characters of wheat.

Variety & Treatment		Grains/spike			Deformed grains/spike			Grain weight/spike (g)			1000-grain weight (g)		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	T_0	37.53 ± 0.55	34.93 ± 0.18	33.80 ± 1.56qr	3.47 ± 0.12	3.67 ± 0.15	4.00 ± 0.12	1.65 ± 0.02	1.61 ± 0.03	1.59 ± 0.07op	49.20 ± 1.16	48.55 ± 0.85	48.21 ± 0.53p
	T_1	36.87 ± 0.35	38.53 ± 0.41	39.40 ± 1.48op	2.93 ± 0.13	2.80 ± 0.12	2.73 ± 0.09	1.75 ± 0.02	1.83 ± 0.03	1.91 ± 0.07l	50.01 ± 0.69	51.05 ± 0.23	51.33 ± 0.62mn
	T_2	38.00 ± 0.23	39.13 ± 0.44	40.60 ± 2.00k-n	2.77 ± 0.12	2.73 ± 0.09	2.67 ± 0.09	1.83 ± 0.02	1.91 ± 0.02	1.95 ± 0.09jkl	51.25 ± 0.72	51.84 ± 1.56	51.99 ± 0.65hi
	T_3	38.87 ± 0.24	39.53 ± 0.48	41.13 ± 1.78jk	2.60 ± 0.12	2.57 ± 0.12	2.53 ± 0.07	1.86 ± 0.02	1.93 ± 0.03	2.01 ± 0.08hi	52.11 ± 0.26	52.38 ± 0.21	52.57 ± 0.66f
	T_4	42.00 ± 0.21	42.93 ± 0.94	44.50 ± 2.44	3.20 ± 0.12	3.13 ± 0.13	3.00 ± 0.06	1.97 ± 0.03	2.10 ± 0.03	2.14 ± 0.10cd	53.10 ± 0.34	53.64 ± 0.77	54.03 ± 0.75b
	T_5	40.03 ± 0.09	41.87 ± 0.85	43.40 ± 1.88ef	2.43 ± 0.09	2.40 ± 0.06	2.33 ± 0.09	1.92 ± 0.04	2.04 ± 0.04	2.09 ± 0.08efg	52.38 ± 0.58	53.11 ± 0.41	53.36 ± 0.73d
	T_6	37.10 ± 0.21	38.87 ± 0.18	40.00 ± 1.96mno	2.87 ± 0.12	2.77 ± 0.12	2.70 ± 0.06	1.79 ± 0.02	1.88 ± 0.02	1.94 ± 0.06l	50.49 ± 0.82	51.56 ± 0.64	51.81 ± 0.66ij
	T_7	39.57 ± 0.29	40.90 ± 0.87	42.70 ± 2.34fgh	2.50 ± 0.12	2.43 ± 0.12	2.40 ± 0.06	1.90 ± 0.02	2.00 ± 0.03	2.05 ± 0.10fgh	52.16 ± 0.14	52.57 ± 0.13	52.75 ± 0.69ef
	T_8	42.73 ± 0.09	43.80 ± 0.53	45.20 ± 1.83c	3.37 ± 0.09	3.50 ± 0.12	3.70 ± 0.06	2.08 ± 0.04	2.16 ± 0.01	2.20 ± 0.08b	53.34 ± 0.56	53.92 ± 0.81	54.21 ± 0.78b
V_2	T_0	36.37 ± 0.32	34.27 ± 0.55	33.20 ± 1.82r	3.27 ± 0.12	3.37 ± 0.09	3.47 ± 0.09	1.59 ± 0.03	1.58 ± 0.03	1.57 ± 0.07p	49.18 ± 0.60	48.25 ± 1.10	48.11 ± 0.53p
	T_1	36.53 ± 0.24	38.13 ± 0.58	39.00 ± 1.80p	2.67 ± 0.12	2.53 ± 0.09	2.50 ± 0.06	1.68 ± 0.03	1.71 ± 0.03	1.75 ± 0.05n	49.63 ± 0.39	50.94 ± 0.69	51.16 ± 0.60n
	T_2	37.67 ± 0.18	39.33 ± 0.68	40.30 ± 1.51k-n	2.52 ± 0.06	2.47 ± 0.12	2.40 ± 0.06	1.73 ± 0.06	1.78 ± 0.03	1.84 ± 0.09m	50.62 ± 0.26	51.63 ± 0.80	51.72 ± 0.64jk
	T_3	38.13 ± 0.24	40.60 ± 0.70	41.00 ± 1.78jkl	2.40 ± 0.12	2.37 ± 0.09	2.33 ± 0.09	1.76 ± 0.03	1.82 ± 0.03	1.90 ± 0.07l	51.15 ± 0.20	52.11 ± 1.10	52.31 ± 0.66g
	T_4	41.00 ± 0.64	42.47 ± 0.66	43.90 ± 2.15de	3.07 ± 0.09	2.97 ± 0.09	2.90 ± 0.12	1.95 ± 0.04	2.06 ± 0.03	2.10 ± 0.10def	52.58 ± 0.33	53.05 ± 1.27	53.54 ± 0.77cd
	T_5	39.73 ± 0.18	40.67 ± 0.47	42.13 ± 2.43hi	2.33 ± 0.09	2.20 ± 0.06	2.17 ± 0.09	1.90 ± 0.03	1.95 ± 0.02	1.99 ± 0.06ijk	51.89 ± 0.17	52.58 ± 0.90	52.75 ± 0.72ef
	T_6	36.70 ± 0.15	38.67 ± 0.77	39.90 ± 1.61no	2.60 ± 0.12	2.50 ± 0.06	2.43 ± 0.12	1.70 ± 0.06	1.75 ± 0.02	1.77 ± 0.07n	50.13 ± 0.79	51.23 ± 0.71	51.43 ± 0.65lm
	T_7	39.43 ± 0.09	40.03 ± 0.70	41.70 ± 2.05ij	2.40 ± 0.06	2.30 ± 0.12	2.27 ± 0.03	1.86 ± 0.01	1.92 ± 0.05	1.94 ± 0.07kl	51.54 ± 0.25	52.20 ± 0.76	52.28 ± 0.70g
	T_8	41.50 ± 0.25	43.10 ± 0.25	44.40 ± 1.92d	3.10 ± 0.10	3.20 ± 0.06	3.37 ± 0.09	2.02 ± 0.05	2.09 ± 0.05	2.13 ± 0.10cde	52.82 ± 0.41	53.49 ± 0.47	53.69 ± 0.78c

Contd...

Variety & Treatment		Grains/spike			Deformed grains/spike			Grain weight/spike (g)			1000-grain weight (g)		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_3	T_0	36.73 ± 0.55	35.93 ± 0.24	34.00 ± 1.77q	3.33 ± 0.12	3.43 ± 0.09	3.70 ± 0.06	1.73 ± 0.05	1.65 ± 0.02	1.63 ± 0.06o	50.19 ± 0.53	49.02 ± 0.99	50.01 ± 0.56o
	T_1	37.53 ± 0.35	38.60 ± 0.46	40.20 ± 1.86l-o	2.80 ± 0.12	2.73 ± 0.12	2.67 ± 0.09	1.78 ± 0.02	1.85 ± 0.02	1.93 ± 0.08l	50.45 ± 0.94	51.16 ± 0.75	51.42 ± 0.63lm
	T_2	38.67 ± 0.41	39.60 ± 0.31	41.10 ± 2.02jk	2.73 ± 0.09	2.67 ± 0.07	2.60 ± 0.06	1.84 ± 0.02	1.94 ± 0.02	2.00 ± 0.06	51.70 ± 0.66	52.05 ± 1.02	52.15 ± 0.68gh
	T_3	39.27 ± 0.24	41.40 ± 0.46	42.60 ± 2.34gh	2.57 ± 0.12	2.47 ± 0.07	2.40 ± 0.12	1.88 ± 0.03	1.98 ± 0.02	2.05 ± 0.08	52.04 ± 0.16	52.53 ± 0.35	52.59 ± 0.71f
	T_4	43.33 ± 0.35	45.10 ± 0.91	46.00 ± 1.86b	3.17 ± 0.09	3.10 ± 0.06	2.93 ± 0.07	2.00 ± 0.07	2.14 ± 0.05	2.18 ± 0.08bc	53.14 ± 0.74	53.85 ± 0.56	54.14 ± 0.77b
	T_5	40.73 ± 0.52	42.23 ± 0.76	43.90 ± 1.90de	2.37 ± 0.07	2.27 ± 0.09	2.30 ± 0.06	1.95 ± 0.07	2.07 ± 0.03	2.09 ± 0.10efg	52.53 ± 0.25	53.25 ± 0.69	53.47 ± 0.72d
	T_6	37.80 ± 0.23	38.60 ± 0.46	40.80 ± 2.12klm	2.73 ± 0.09	2.70 ± 0.12	2.57 ± 0.03	1.82 ± 0.05	1.88 ± 0.04	1.95 ± 0.07jkl	50.83 ± 0.68	51.37 ± 0.43	51.55 ± 0.67kl
	T_7	40.20 ± 0.70	41.57 ± 0.50	43.10 ± 1.87efg	2.50 ± 0.06	2.40 ± 0.06	2.37 ± 0.03	1.91 ± 0.06	2.03 ± 0.02	2.05 ± 0.06gh	52.21 ± 0.12	52.75 ± 0.38	52.90 ± 0.72e
	T_8	44.00 ± 0.12	46.33 ± 0.41	47.60 ± 1.79a	3.23 ± 0.03	3.40 ± 0.06	3.53 ± 0.09	2.13 ± 0.07	2.21 ± 0.08	2.26 ± 0.10a	53.66 ± 0.65	54.02 ± 0.16	54.45 ± 0.77a
LS		NS	NS	**	NS	NS	NS	NS	NS	**	NS	NS	**
CV (%)		1.52	2.55	1.09	6.12	5.85	4.80	3.69	2.90	1.48	1.90	3.12	1.23

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

4.4.13 Grain yield

The varietal response on grain yield was significant all over the study period. From the analyzed records, the highest mean grain yield of 3.38 t/ha was produced from the V_3, whereas the minimum grain yield of 3.17 t/ha was reported from the V_1 in the year 2016-2017 (Fig. 21). Like previous year similar trends were noticed in 2017-2018, where with slight increment varietal performance was ranked as ascending order V_2 (3.30 t/ha) >V_1 (3.37 t/ha) >V_3 (3.47 t/ha) (Fig. 22). At the end of three years study, the data showed an increased trend in the last year over the previous two years. The maximum grain yield (3.59 t/ha) was found in V_3 oppositely the least grain yield (3.40 t/ha) had in V_2 (Fig. 23).

Application of different soil amendments under this investigation was generated significant variation on the grain yield of wheat (Fig. 24, 25 and 26). The beneficial effects of different treatments on the grain yield was expressed in the range 4.08-2.67 t/ha in 2016-2017, here the maximum value was obtained from T_8 (4.08 t/ha) followed by T_4 (3.77 t/ha) and the least value was found in T_0 (2.67 t/ha). In 2017-2018, with the minor enhancement of grain yield to previous year treatments was demonstrated. There grain yield 4.13 t/ha was the superior, on the other hand, grain yield 2.54 t/ha was the inferior derived from T_8 and T_0, respectively. The production of grain yield under various soil amendments went upwards in the last year of study. In the last year, influences of different treatments on grain yield were found to be ranked in the following descending order T_8 (4.25 t/ha) >T_4 (4.09 t/ha) >T5 (3.85 t/ha) >T_7 (3.64 t/ha) >T_3 (3.60 t/ha) >T_2 (3.34 t/ha) >T_6 (3.27 t/ha) >T_1 (3.05 t/ha) >T_0 (2.36 t/ha).

In grain production there was a non-significant interaction among the treatment combinations at harvest, except final year of the investigation. Though there was no significant variation among the treatment combinations in 2016-2017, but the most efficient treatment combination for higher grain yield was found in V_3T_8 (4.10 t/ha). Without major change, minor increase in grain yield as like tendency was observed from the treatment combinations in 2017-2018. Here the treatment combination V_3T_8 yielded the maximum grain (4.17 t/ha), while the minimum was recorded in V_3T_0 (2.55 t/ha). The treatment combination V_3T_8 was produced the highest grain yield (4.35 t/ha) at the last year of the research which was the best treatment combination for grain yield.

The treatment combination V_1T_8 was defined as the second major (4.25 t/ha) followed by V_3T_4 (4.14 t/ha) on the basis of grain production records, whereas V_3T_0 had the least (2.34 t/ha) grain production shown in Table 33.

4.4.14 Straw yield

The Fig. 21, 22 and 23 represent that the data related to straw yield was affected significantly by the different wheat varieties. Among the different varieties, the maximum straw yield (4.76 t/ha) was recorded in V_3 and it was statistically different from V_1 (4.69 t/ha) and V_2 (4.64 t/ha) in 2016-2017. The straw yield of wheat resulted in a little increase in 2017-2018 and that was recorded the greater and the lesser from V_3 (4.84 t/ha) and V_1 (4.75 t/ha). As in 2017-2018, the parallel varietal effect on straw yield was revealed in 2018-2019 and had the maximum production at V_3 (4.96 t/ha) which was followed by V_2 (4.89 t/ha) and V_1 (4.87 t/ha), respectively.

Soil amendments application significantly influenced the straw yield all over the research period (Fig. 24, 25 and 26). The positive effect of organic amendments in straw yield was greater (5.26 t/ha) in T_8 than other treatments, even though the lowest straw yield was obtained from T_0 (4.30 t/ha) in the period of 2016-2017. The straw yield also varied considerably under the treatments studied in 2017-2018. The maximum (5.36 t/ha) straw yield was recorded by T_8, but the minimum (4.17 t/ha) straw yield was reported to T_0. Among the different soil amendments, T_8 (5.40 t/ha) was performed superior besides T_4 (5.31 t/ha) to other treatments in 2018-2019. Rest of the treatments were showed also significant difference ranked as descending in T_5 (5.14 t/ha), T_7 (5.05 t/ha), T_3 (4.93 t/ha), T_6 (4.83 t/ha), T_2 (4.73 t/ha), T_1 (4.60 t/ha), while the lowest one was found in T_0 (4.18 t/ha).

The straw yield showed significant variations at various combinations of treatments and varieties during the research period (Table 33). Increasing development of straw yield was noticed under different treatment combinations in 2016-2017, where the combination V_2T_8 (5.53 t/ha) was produced greater straw yield followed by V_1T_8 (5.22 t/ha), V_3T_8 (5.20 t/ha) and V_2T_4 (5.16 t/ha), while the lowest was observed in V_2T_0 (4.20 t/ha). On the other hand, with statistical significance the maximum straw yield was recorded in V_2T_8 (5.48 t/ha) followed by V_1T_8 (5.34 t/ha) and V_3T_8 (5.26 t/ha) in 2017-2018. Comparable results were found in 2018-2019 with the previous two years regarding straw yield. But the increased straw yield value was documented in case of V_2T_8 (5.50 t/ha) and oppositely the decreased value was observed in case of V_1T_0 (4.18 t/ha).

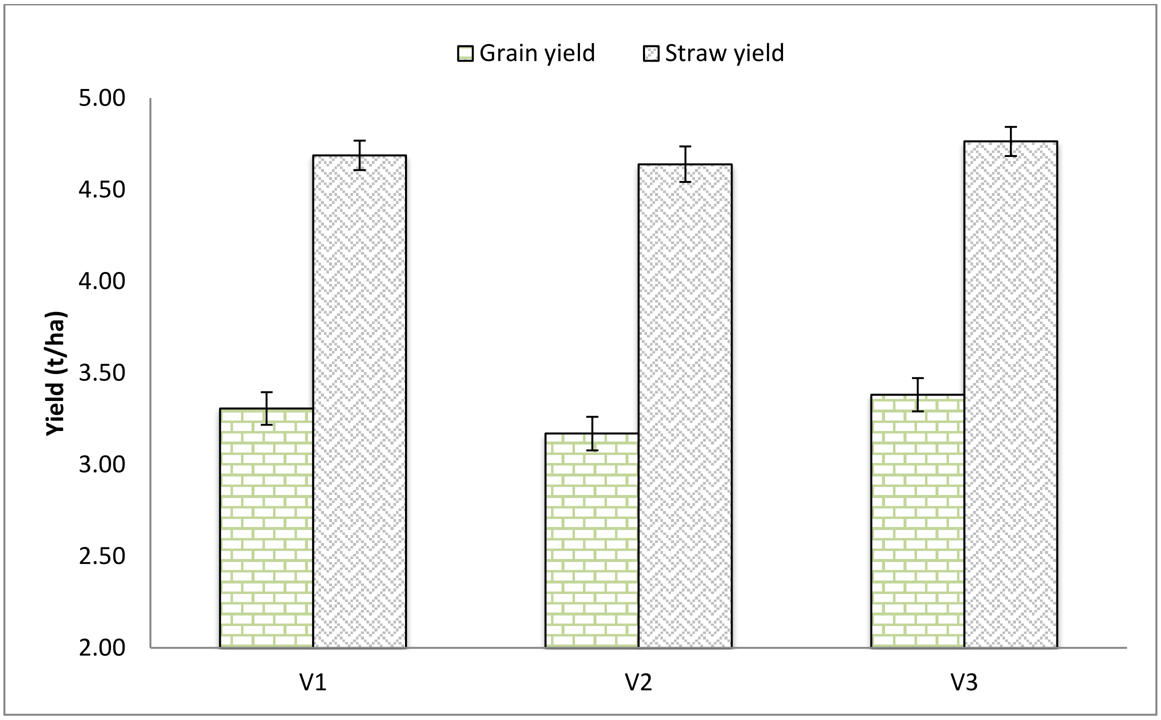

Fig. 21: Effect of variety on grain and straw yield of wheat in 2016-2017.

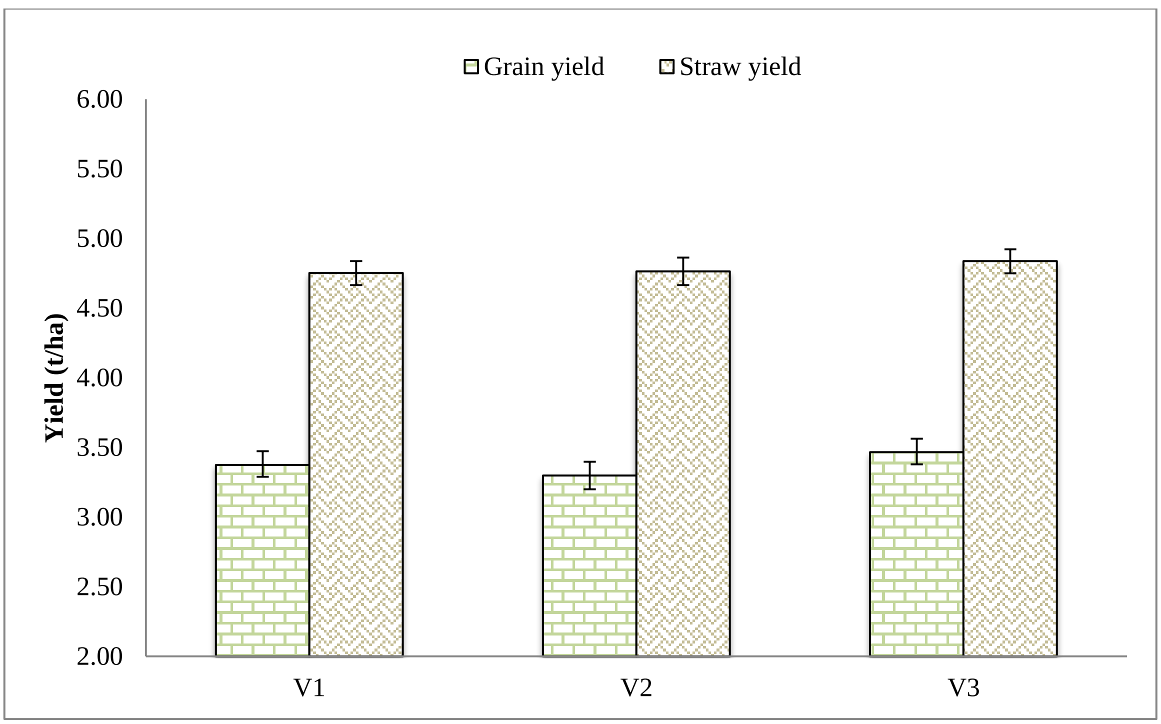

Fig. 22: Effect of variety on yield and straw yield of wheat in 2017-2018.

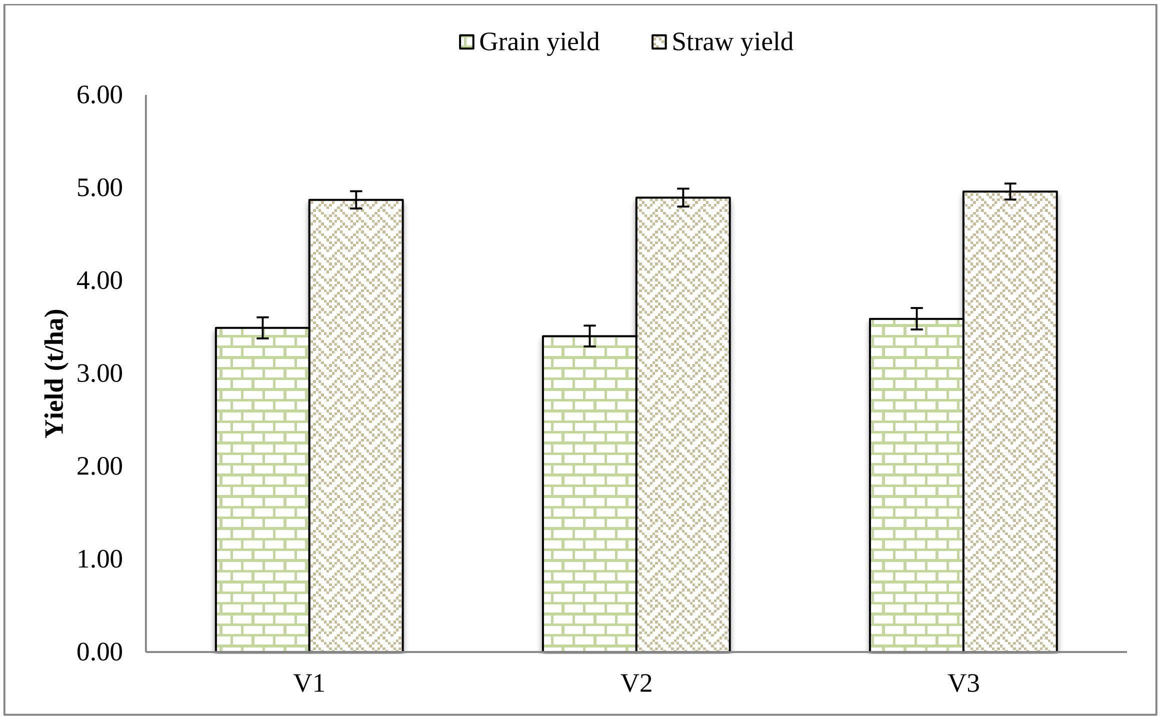

Fig. 23: Effect of variety on grain and straw yield of wheat in 2018-2019.

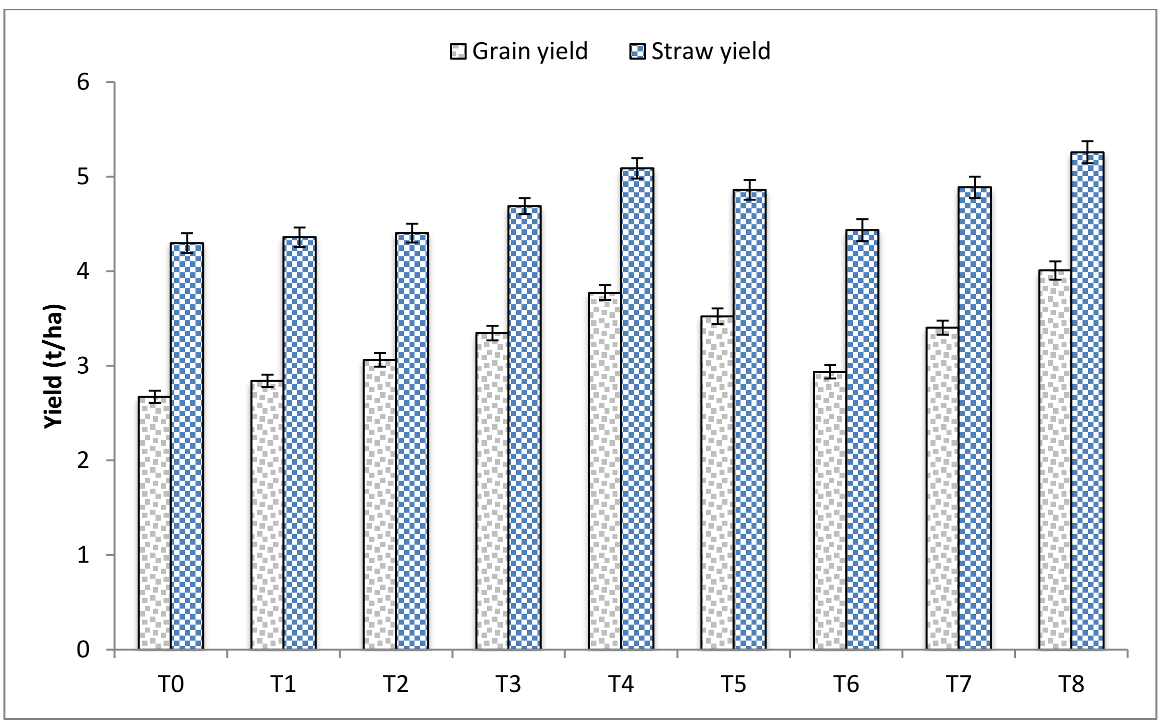

Fig. 24: Effect of organic and probiotic soil amendments on grain and straw yield of wheat in 2016-2017.

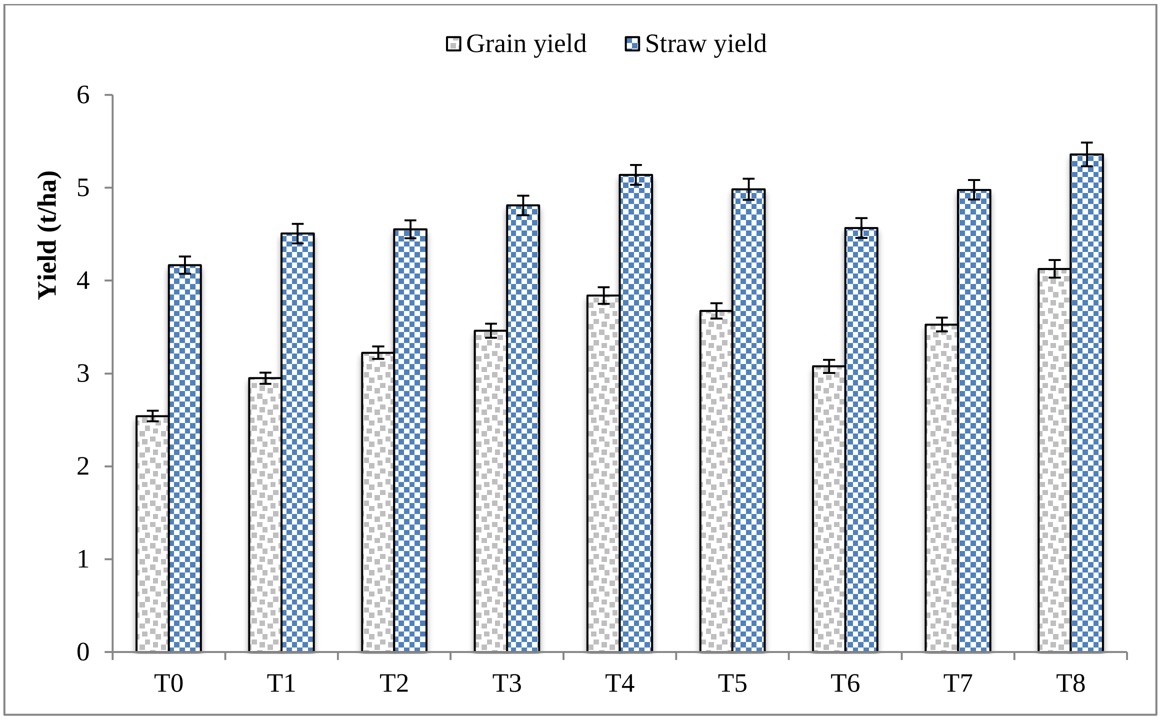

Fig. 25: Effect of organic and probiotic soil amendments on grain and straw yield of wheat in 2017-2018.

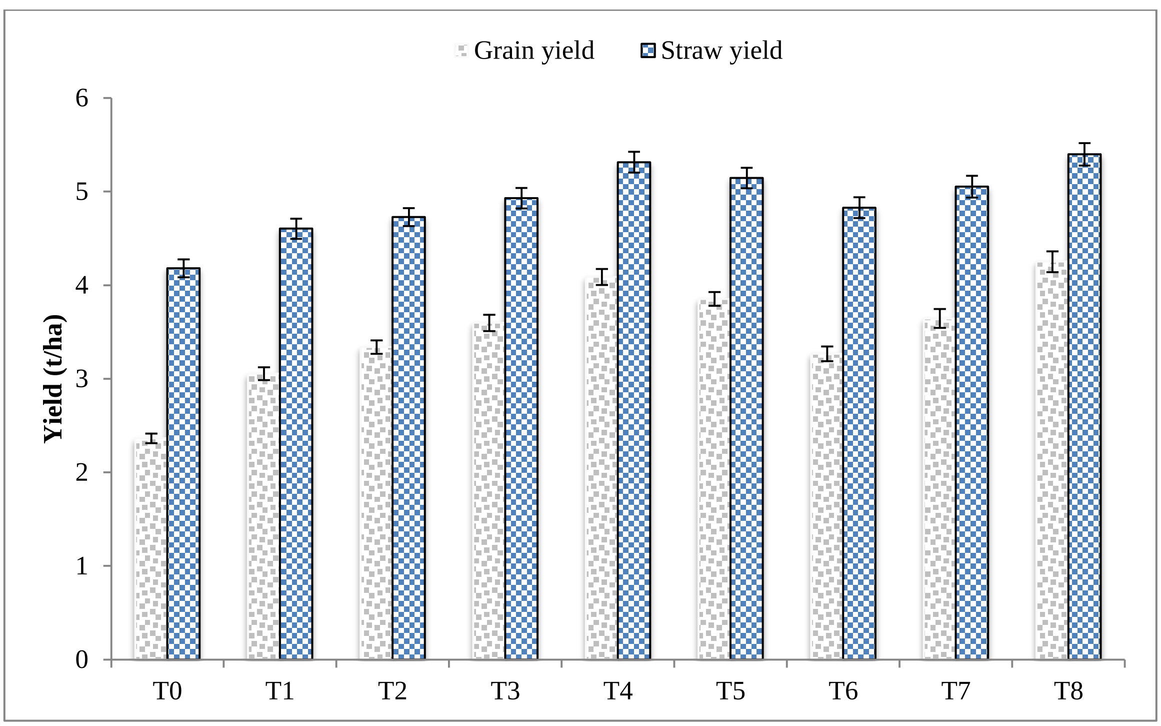

Fig. 26: Effect of organic and probiotic soil amendments on grain and straw yield of wheat in 2018-2019.

4.4.15 Harvest index

A summary of varietal influences of this study on harvest index was described in Fig. 27. The highest harvest index (41.38%) was noted by the variety V_3 and this was statistically at par with the V_1 (41.27%) in 2016-2017, at the same time the smallest harvest index (40.47%) was obtained in V_2. Likewise previous year, the harvest index of the second year varied significantly with the variety factor. But the scale of increase in harvest index was a little bit more, where the V_3 was reported the maximum harvest index (41.62%) and the lowest (40.80%) in V_2. During 2018-2019, the maximum harvest index (41.74%) was recorded with V_3, though the V_2 demonstrated the minimum index (40.81%).

The three years harvest index trend of wheat varied under different soil amendments. In 2016-2017, application of chemical fertilizer (T_8) gave the greater harvest index (43.28%) and poultry manure (T_4) had the second highest value (42.60%) which had statistical equality (42.02%) with T_5. On the other hand, the least result (38.36%) was obtained from T_0. In the next year, treatments were further produced with the similar effect on harvest index with the utmost value (43.53%) and the lowest value (37.93%) by T_8 and T_0, respectively. Extension of the study and further evaluation of data, revealed the highest value 44.05% followed by 43.48% and the lowest one 36.13% was derived from T_8, T_4 and T_0 during 2018-2019 (Fig. 28).

Results in Table 33 indicate that harvest index by different treatment combinations were non-significant in 2016-2017, but significant in 2017-2018 and 2018-2019. The most effective treatment combination for higher harvest index was recorded from V_3T_8 (44.08%), but the minimum was noted from V_3T_8 (38.29%) for the year 2016-2017. As previous year, the treatment combination V_3T_8 resulted significantly the maximum harvest index (44.25%) after that V_1T_8 (43.64%) and V_3T_4 (43.28%), while the minimum was recorded in V_2T_0 (37.69%) from the year 2017-2018. In the last year of the research, the treatment V_3T_8 was produced the highest harvest index (45.02%) that was the best treatment combination for harvest index. The treatment V_1T_8 was defined as the second major (44.14%) followed by V_3T_4 (43.91%) and V_1T_4 (43.72%) on the basis of harvest index records, whereas V_2T_0 had the least harvest index (35.91%).

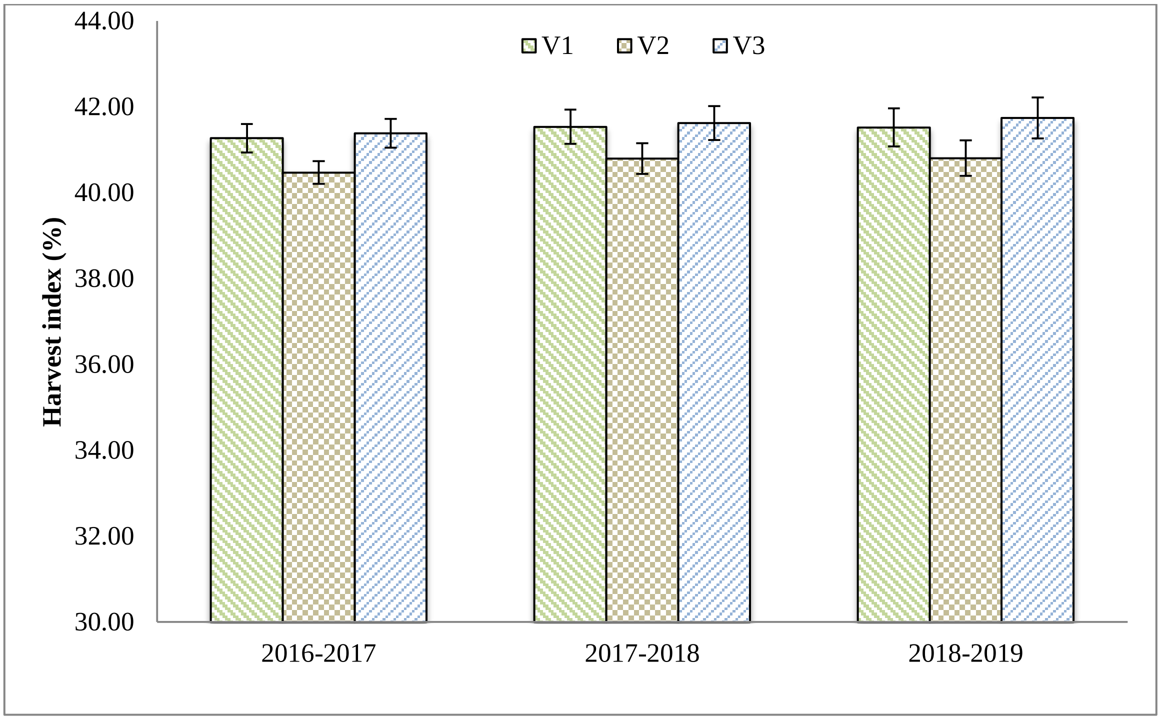

Fig. 27: Effect of variety on harvest index of wheat in 2016-2017, 2017-2018 and 2018-2019.

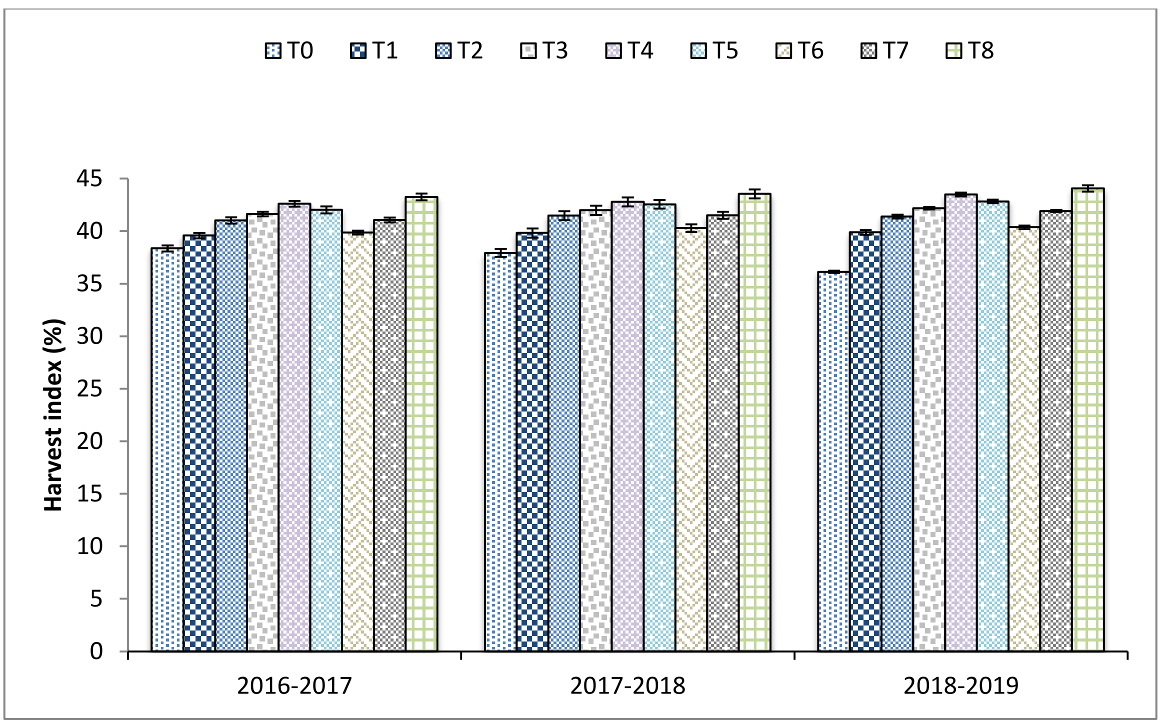

Fig. 28: Effect of organic and probiotic soil amendments on harvest index of wheat in 2016-2017, 2017-2018 and 2018-2019.

Table 33: Interaction effects of variety and soil amendments on grain yield, straw yield and harvest index of wheat.

Variety & Treatment		Grain yield (t/ha)			Straw yield (t/ha)			Harvest index (%)		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	T_0	2.68 ± 0.12	2.55 ± 0.11	2.36 ± 0.10p	4.32 ± 0.20klm	4.21 ± 0.21o	4.12 ± 0.17l	38.29 ± 0.61	37.75 ± 0.72lm	36.41 ± 0.07l
	T_1	2.88 ± 0.09	2.93 ± 0.09	3.01 ± 0.10o	4.48 ± 0.22hi	4.52 ± 0.20lm	4.59 ± 0.23i	39.47 ± 0.52	40.02 ± 0.91j	39.64 ± 0.39k
	T_2	3.11 ± 0.13	3.22 ± 0.13	3.33 ± 0.14kl	4.35 ± 0.16jkl	4.47 ± 0.19mn	4.63 ± 0.17i	41.68 ± 0.54	41.93 ± 0.85f	41.83 ± 0.07hi
	T_3	3.36 ± 0.14	3.45 ± 0.14	3.57 ± 0.15i	4.63 ± 0.16g	4.72 ± 0.19hi	4.85 ± 0.17f	42.04 ± 0.17	42.58 ± 0.65de	42.39 ± 0.17fg
	T_4	3.77 ± 0.13	3.82 ± 0.19	4.10 ± 0.15cd	5.00 ± 0.20d	5.05 ± 0.22e	5.28 ± 0.22c	43.04 ± 0.15	43.06 ± 0.53bcd	43.72 ± 0.15bc
	T_5	3.57 ± 0.14	3.66 ± 0.15	3.85 ± 0.15f	4.87 ± 0.17ef	4.94 ± 0.24fg	5.12 ± 0.24d	42.29 ± 0.11	42.88 ± 0.72cd	42.93 ± 0.16de
	T_6	2.95 ± 0.12	3.10 ± 0.13	3.30 ± 0.13klm	4.42 ± 0.22ij	4.57 ± 0.19kl	4.85 ± 0.24f	40.05 ± 0.21	40.45 ± 0.79ij	40.51 ± 0.21j
	T_7	3.42 ± 0.16	3.51 ± 0.16	3.65 ± 0.17hi	4.90 ± 0.21ef	4.95 ± 0.20fg	5.02 ± 0.22e	41.10 ± 0.62	41.51 ± 0.37fgh	42.09 ± 0.07ghi
	T_8	4.01 ± 0.16	4.13 ± 0.17	4.25 ± 0.18b	5.22 ± 0.24b	5.34 ± 0.23b	5.38 ± 0.25b	43.46 ± 0.14	43.64 ± 0.92b	44.14 ± 0.12b
V_2	T_0	2.57 ± 0.10	2.46 ± 0.09	2.34 ± 0.09p	4.20 ± 0.21n	4.08 ± 0.17p	4.18 ± 0.21kl	37.99 ± 0.27	37.69 ± 0.68m	35.91 ± 0.27m
	T_1	2.73 ± 0.14	2.85 ± 0.09	2.93 ± 0.10o	4.27 ± 0.18mn	4.42 ± 0.20n	4.51 ± 0.19j	38.98 ± 0.26	39.26 ± 0.70k	39.40 ± 0.24k
	T_2	2.90 ± 0.13	3.16 ± 0.14	3.24 ± 0.14lmn	4.30 ± 0.20klm	4.55 ± 0.18l	4.72 ± 0.18h	40.28 ± 0.55	41.01 ± 0.84hi	40.69 ± 0.14j
	T_3	3.25 ± 0.15	3.38 ± 0.14	3.46 ± 0.14j	4.56 ± 0.12gh	4.79 ± 0.21h	4.83 ± 0.22fg	41.56 ± 0.46	41.41 ± 0.88fgh	41.75 ± 0.13hi
	T_4	3.70 ± 0.17	3.76 ± 0.17	4.02 ± 0.19de	5.16 ± 0.21bc	5.19 ± 0.20cd	5.37 ± 0.22b	41.78 ± 0.14	42.02 ± 0.90ef	42.80 ± 0.14ef
	T_5	3.37 ± 0.12	3.58 ± 0.13	3.77 ± 0.14fg	4.86 ± 0.24ef	5.00 ± 0.23efg	5.16 ± 0.19d	40.98 ± 0.35	41.77 ± 0.84fg	42.22 ± 0.02gh
	T_6	2.81 ± 0.11	2.97 ± 0.12	3.15 ± 0.13n	4.24 ± 0.20mn	4.44 ± 0.18n	4.76 ± 0.22gh	39.87 ± 0.14	40.11 ± 0.79j	39.84 ± 0.14k
	T_7	3.29 ± 0.12	3.45 ± 0.13	3.57 ± 0.14i	4.81 ± 0.21f	4.93 ± 0.20fg	5.00 ± 0.22e	40.64 ± 0.15	41.20 ± 0.74gh	41.67 ± 0.11i
	T_8	3.91 ± 0.19	4.08 ± 0.20	4.15 ± 0.20c	5.35 ± 0.22a	5.48 ± 0.25a	5.50 ± 0.23a	42.21 ± 0.19	42.70 ± 0.60cd	42.98 ± 0.18de

Contd...

Variety & Treatment		Grain yield (t/ha)			Straw yield (t/ha)			Harvest index (%)		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_3	T_0	2.77 ± 0.12	2.61 ± 0.11	2.39 ± 0.10p	4.37 ± 0.20jk	4.21 ± 0.17o	4.24 ± 0.20k	38.80 ± 0.61	38.34 ± 0.84l	36.05 ± 0.07lm
	T_1	2.92 ± 0.11	3.07 ± 0.12	3.22 ± 0.12mn	4.33 ± 0.19j-m	4.58 ± 0.21kl	4.71 ± 0.20h	40.29 ± 0.16	40.18 ± 0.86j	40.62 ± 0.12j
	T_2	3.18 ± 0.11	3.29 ± 0.11	3.44 ± 0.12j	4.56 ± 0.18gh	4.64 ± 0.19jk	4.83 ± 0.20fg	41.10 ± 0.16	41.52 ± 0.70fgh	41.61 ± 0.13i
	T_3	3.43 ± 0.15	3.55 ± 0.15	3.76 ± 0.16fg	4.87 ± 0.14ef	4.92 ± 0.21g	5.11 ± 0.21d	41.28 ± 0.35	41.94 ± 0.95f	42.38 ± 0.07fg
	T_4	3.85 ± 0.15	3.94 ± 0.16	4.14 ± 0.17c	5.10 ± 0.22c	5.17 ± 0.21d	5.29 ± 0.23c	43.02 ± 0.62	43.28 ± 0.84bc	43.91 ± 0.06b
	T_5	3.63 ± 0.18	3.78 ± 0.19	3.94 ± 0.19e	4.85 ± 0.23ef	5.01 ± 0.20ef	5.15 ± 0.23d	42.78 ± 0.51	43.01 ± 0.69bcd	43.33 ± 0.19cd
	T_6	3.05 ± 0.13	3.16 ± 0.14	3.35 ± 0.15k	4.64 ± 0.19g	4.69 ± 0.23ij	4.87 ± 0.20f	39.66 ± 0.51	40.31 ± 0.49j	40.75 ± 0.07j
	T_7	3.50 ± 0.12	3.62 ± 0.13	3.71 ± 0.15gh	4.95 ± 0.24de	5.05 ± 0.22e	5.13 ± 0.25d	41.45 ± 0.33	41.79 ± 0.78fg	41.98 ± 0.24ghi
	T_8	4.10 ± 0.19	4.17 ± 0.19	4.35 ± 0.20a	5.20 ± 0.23b	5.26 ± 0.26bc	5.31 ± 0.23bc	44.08 ± 0.55	44.25 ± 0.62a	45.02 ± 0.07a
LS		NS	NS	*	**	**	**	NS	*	**
CV (%)		1.39	1.55	1.57	1.10	0.93	.084	1.61	0.89	0.65

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, ** = 1% Level of significance, * = 5% Level of significance, CV = Co-efficient of variation.

4.5 Seed quality

4.5.1 Germination

Seed germination differed significantly due to variety factor under the whole research period (Table 34). Significantly the higher value of germination was noticed from V_3 (82.42%), on the contrary, the lesser value was found in V_1 (78.83%) in the period of 2016-2017. The similar movement as previous year was reported by V_3 and that was presented the maximum germination (83.41%) followed by V_1 (82.04%) with statistical identity in 2017-2018. However in the final year, germination of seed was ranked as the descending order V_3 (85.79%) >V_1 (84.24%) >V_2 (83.34%).

In the present experiment, soil amendments influenced the germination of seed with statistical variation. The percentage of seed germination in control (T_0) was 70.50% which increased considerably with addition of the different soil amendments in the first year (2016-2017). There the highest germination was observed in T_4 (88.27%) and subsequently in T_5 (84.75%) and T_7 (83.59%) in comparison with the rest of the treatments. In the second year (2017-2018), equivalent results were derived from the various treatments, where 89.93% was the best performance and 72.53% was the lowest one provided by T_4 and T_5, respectively. With the advancement of germination percentage, the treatment T_4 highly enhanced (92.08%) the germination followed by T_5 (88.89%), oppositely the treatment T_0 had lower effect (74.78%) on germination in the final year of the study (Table 35).

Though the interaction of variety and soil amendment treatment produced significant variation in the first year, but non-significant result was obtained from the next two years. The treatment V_3T_4 resulted in the maximum germination (90.67%) and subsequently in V_1T_4 (88.38%), while the minimum were found in V_2T_0 (68.93%) in 2016-2017. In the second year, interactions demonstrated the same tendency with minor increase in germination as the previous year showing greater (91.58%) and lowest (70.33%) was found in V_3T_4 and V_2T_0. In the final year, the V_3T_4 was also demonstrated the highest value (94.42%) followed by V_1T_4 (92.00%) on the basis of germination percentage, whereas V_2T_0 showed the lowest (72.50%) germination percentage in Table 36.

4.5.2 Vigor index

The Table 34 revealed that the records related to vigor indices were affected significantly by the function of different wheat varieties. Among the different varieties, the greater vigor index (31.85) was recorded in V_1 and it was statistically different from V_3 (31.65) and V_2 (31.15) in 2016-2017. The vigor index of wheat was found to increase in 2017-2018 and that was reported the higher and the lower from V_3 (35.93) and V_2 (33.85), respectively. As in 2017-2018, the parallel varietal effect on vigor index was recorded in 2018-2019, where the maximum value (37.75) was recorded in V_3 which was followed by V_1 (36.36) and V_2 (35.20).

The data of vigor index of wheat under different soil amendments showed significantly positive result in the consecutive year of experiment. In 2016-2017, wheat plants that treated with poultry manure (T_4) had the highest vigor index (35.99) followed by *Trichoderma harzianum* (T_5) with the value 34.57, while plants in the control plot had the lowest vigor index (24.70). In 2017-2018, a trend of enhancement was noted against various treatments on vigor index. At that time, the highest vigor index (39.48) was noted under T_4 and the second highest (37.30) in T_5 which was statistically interlinked with T_3 (36.84), while T_0 had the lowest mean (27.49). Comparable trend of vigor index from respective treatment showed that 41.54 were higher subsequently 39.26 and 28.84 was the lowest one obtained in $T_{4,}$ T_5 and T_0, respectively in 2018-2019 (Table 35).

There was a significant interaction effect of treatments on vigor index except in the final year of the investigation (Table 36). The major efficient treatment for higher vigor index was recorded from V_1T_4 (37.44) followed by V_1T_5 (35.65) and V_3T_4 (35.44), but the minimum was noted from V_2T_0 (24.52) for the year 2016-2017. In 2017-2018, the V_3T_4 resulted in the maximum vigor index (42.47) after that ranked V_1T_4 (38.56) and V_3T_5 (38.42), while the minimum was recorded in V_2T_0 (26.58). In the last year of the research, the treatment combination did not show any significant effect. Though, the combination V_3T_4 produced the highest vigor index (43.79), whereas V_2T_0 had the least vigor index (27.69).

4.5.3 Total soluble protein content

Effect of wheat variety on protein content was affected significantly all over the study period (Table 34). From the experimental findings, it was revealed that the protein content of seed in the period of 2016-2017 showed as descending V_1 (84.62 mg/g FW), V_3 (83.67 mg/g FW) and V_2 (83.19 mg/g FW). Among the varieties, the maximum protein content was noticed from V_3 (86.31 mg/g FW), but the minimum was found in V_2 (83.97 mg/g FW) for the production year 2017-2018. A little bit advancement in seed protein content was recorded in the year 2018-2019, where the greater value was noted by V_3 (86.91 mg/g FW) and the minor was in V_2 (85.73 mg/g FW).

The results presented in Table 35 demonstrate a significant variation on the protein content of seed by the different soil amendments in the whole research time. The obtained results in 2016-2017 showed that the protein content of seed varied significantly from 77.31 to 93.32 mg/g FW. Conversely, the higher protein content of seed (93.32 mg/g FW) was recorded in T_8 followed by T_4 (88.17 mg/g FW), while the lesser protein content of seed was noticed in T_0 (77.31 mg/g FW). The data concerned with protein content of seed in 2017-2018 clearly explained that the maximum protein content (93.80 mg/g FW) was observed with T_8, while the least in control (77.47 mg/g FW). In the last year of study, the protein content of seed under various soil amendments was to have slightly increased. Influences of different treatments on protein content of seed were found to be highest in T_8 (96.43 mg/g FW) followed by T_4 (92.56 mg/g FW), whereas the lowest was found in control (79.10 mg/g FW).

The protein content of wheat seed was responded significantly due to interaction of varieties and soil amendments throughout experimental duration (Table 36). In general, as the T_8 individually presented the greater value of protein content thus the V_1T_8 interaction produced the maximum protein content of seed (95.28 mg/g FW) which was statistical identity with V_3T_8 (94.19 mg/g FW) and oppositely the minimum (77.06 mg/g FW) protein content of seed noticed from V_2T_0 in the season 2016-2017. In the case of season 2017-2018, the treatment combination V_3T_8 resulted in the maximum protein content of seed (96.07 mg/g FW), while the minimum was recorded in V_1T_0 (76.72 mg/g FW). In the final year (2018-2019) of this study, the treatment combination V_3T_8 was produced the highest protein content of seed (100.12 mg/g FW), whereas V_2T_0 had the least protein content (78.16 mg/g FW).

Table 34: Effect of variety on seed quality of wheat.

Variety	Germination (%)			Vigor index			Soluble protein content (mg/g FW)		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	78.83 ± 1.04c	82.04 ± 1.07a	84.24 ± 1.21b	31.85 ± 0.64a	34.40 ± 0.59b	36.36 ± 0.75b	84.62 ± 0.33a	85.04 ± 0.53b	86.86 ± 0.42a
V_2	79.34 ± 1.09b	80.41 ± 1.18b	83.34 ± 1.04c	31.15 ± 0.72c	33.85 ± 0.70b	35.20 ± 0.60c	83.19 ± 1.01b	83.97 ± 1.08c	85.73 ± 1.06b
V_3	82.42 ± 1.08a	83.41 ± 1.08a	85.79 ± 1.05a	31.65 ± 0.74b	35.93 ± 0.76a	37.75 ± 0.66a	83.67 ±1.05b	86.31 ± 1.13a	86.91 ± 1.23a
LS	**	**	**	**	**	**	**	**	**
CV (%)	0.82	3.34	1.79	0.97	3.16	2.91	1.58	1.61	1.42

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI-28, V_2 = BARI-29, V_3 = BARI-30, DAS = Days after sowing, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

Table 35: Effect of organic and probiotic soil amendments on seed quality of wheat.

Treatment	Germination (%)			Vigor index			Soluble protein content (mg/g FW)		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
T_0	70.50 ± 0.92h	72.53 ± 0.93g	74.78 ± 0.85g	24.70 ± 0.42h	27.49 ± 0.40f	28.84 ± 0.27f	77.31 ± 0.28e	77.47 ± 0.58e	79.10 ± 0.42e
T_1	75.31 ± 1.08g	77.54 ± 1.02f	79.67 ± 1.18f	28.20 ± 0.55g	32.52 ± 0.54e	34.39 ± 0.36e	78.20 ± 0.45e	79.68 ± 1.05d	79.58 ± 0.52e
T_2	78.14 ± 0.82f	80.88 ± 0.98de	83.67 ± 0.96d	31.69 ± 0.85e	34.42 ± 0.96d	35.93 ± 0.38d	80.25 ± 0.46d	80.97 ± 0.73cd	82.98 ± 0.39d
T_3	81.08 ± 0.85d	83.86 ± 0.92bc	86.17 ± 0.94c	32.60 ± 0.43d	36.84 ± 0.49b	38.36 ± 0.34b	80.20 ± 1.02d	81.98 ± 1.44c	82.24 ± 1.28d
T_4	88.27 ± 1.05a	89.93 ± 1.01a	92.08 ± 1.24a	35.99 ± 0.73a	39.48 ± 0.84a	41.54 ± 0.58a	88.17 ± 1.89b	93.30 ± 0.90a	92.56 ± 0.70b
T_5	84.75 ± 1.06b	86.52 ± 1.15b	88.89 ± 0.84b	34.57 ± 0.52b	37.30 ± 0.58b	39.26 ± 0.46b	87.59 ± 0.59b	88.30 ± 0.66b	91.03 ± 0.99c
T_6	78.76 ± 0.89e	78.40 ± 1.46ef	81.83 ± 1.42e	30.21 ± 0.46f	34.68 ± 0.33d	35.37 ± 0.33de	81.51 ± 0.72c	81.31 ± 0.63c	82.62 ± 0.70d
T_7	83.59 ± 0.93c	83.33 ± 1.05cd	86.28 ± 0.96c	33.56 ± 0.43c	35.78 ± 0.38c	36.98 ± 0.42c	87.88 ± 0.58b	89.17 ± 0.83b	91.99 ± 0.67bc
T_8	81.37 ± 0.86d	84.57 ± 1.05bc	86.76 ± 01.16c	32.46 ± 0.50d	34.03 ± 0.34d	37.27 ± 0.48c	93.32 ± 1.08a	93.80 ± 1.20a	96.43 ± 1.14a
LS	**	**	**	**	**	**	**	**	**
CV (%)	0.82	3.34	1.79	0.97	3.16	2.91	1.58	1.61	1.42

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

Table 36: Interaction effects of variety and soil amendments on seed quality of wheat.

Variety & Treatment		Germination (%)			Vigor index			Soluble protein content (mg/g FW)		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_1	T_0	70.17 ± 1.42m	72.99 ± 1.48	75.25 ± 1.52	25.24 ± 0.36o	27.50 ± 0.40l	28.95 ± 0.59	77.20 ± 0.24ij	76.72 ± 1.79l	80.17 ± 0.71jk
	T_1	72.65 ± 1.68l	77.58 ± 1.85	79.17 ± 1.83	27.32 ± 0.55n	33.59 ± 0.44hij	34.98 ± 0.81	77.58 ± 0.91hij	78.34 ± 0.47jkl	80.02 ± 0.94jk
	T_2	76.23 ±1.46j	80.32 ± 1.74	83.67 ± 0.97	32.33 ± 0.75h	33.31 ± 0.67ij	36.20 ± 0.42	81.35 ± 0.02efg	81.85 ± 0.97gh	84.01 ± 0.75h
	T_3	78.62 ± 1.14i	83.74 ± 2.18	86.33 ± 1.67	33.31 ± 0.39g	36.01 ± 0.42c-f	37.51 ± 0.54	82.66 ± 0.26e	85.53 ± 0.23ef	86.58 ± 0.26g
	T_4	88.38 ± 2.04b	90.16 ± 1.56	92.00 ± 1.59	37.44 ± 0.97a	38.56 ± 0.33b	41.02 ± 0.95	93.70 ± 0.82a	95.11 ± 1.94ab	92.28 ± 0.82cde
	T_5	84.57 ± 2.20de	85.44 ± 1.97	88.08 ± 2.03	35.65 ± 0.72b	36.10 ± 0.52c-f	38.82 ± 1.01	86.02 ± 0.02d	87.39 ± 0.02e	90.39 ± 0.53ef
	T_6	74.27 ± 1.50k	79.48 ± 1.72	81.65 ± 1.65	29.37 ± 0.42l	34.77 ± 0.50f-i	35.77 ± 0.52	82.10 ± 1.67ef	81.22 ± 1.18ghi	83.96 ± 1.23h
	T_7	82.73 ± 1.43fg	82.37 ± 1.80	84.82 ± 1.71	34.52 ± 0.80e	35.86 ± 0.83c-g	36.89 ± 0.85	85.66 ± 0.48d	86.32 ± 0.51e	90.06 ± 1.31f
	T_8	81.84 ± 2.13g	86.28 ± 1.91	87.17 ± 1.76	31.48 ± 0.55ij	33.87 ± 0.59g-j	37.12 ± 0.64	95.28 ± 0.81a	92.93 ± 2.16bc	94.32 ± 0.26bc
V_2	T_0	68.95 ± 1.39n	70.33 ± 1.02	72.50 ± 1.05	24.52 ± 0.35p	26.58 ± 0.15l	27.69 ± 0.97	77.06 ± 0.90ij	79.32 ± 0.21ijk	78.98 ± 0.70k
	T_1	74.58 ± 1.08k	75.98 ± 1.54	78.33 ± 2.04	28.45 ± 0.66m	30.74 ± 0.71k	32.84 ± 0.99	77.62 ± 0.21hij	76.60 ± 1.12l	78.57 ± 0.46k
	T_2	77.82 ± 1.80i	80.11 ± 1.85	82.58 ± 1.43	31.21 ± 0.63j	32.19 ± 0.93jk	33.05 ± 0.86	78.48 ± 0.21hij	79.01 ± 0.24ijkl	81.89 ± 0.25hij
	T_3	82.29 ± 1.43g	83.22 ± 1.44	84.92 ± 1.72	32.24 ± 0.37h	36.86 ± 1.17b-e	38.39 ± 0.78	76.69 ± 1.34j	76.87 ± 1.79kl	78.26 ± 1.37k
	T_4	85.76 ± 1.65c	88.04 ± 2.03	89.83 ± 1.30	35.08 ± 0.91cd	37.42 ± 0.76bcd	39.81 ± 0.58	89.79 ± 0.24b	91.42 ±0.81cd	94.61 ± 0.57b
	T_5	83.53 ± 0.97ef	85.28 ± 1.88	87.92 ± 1.71	33.28 ± 0.58g	37.37 ± 1.08bcd	38.53 ± 0.89	87.06 ± 0.77cd	87.39 ± 0.49e	89.81 ± 0.27f
	T_6	80.29 ± 1.62h	74.17 ± 2.14	80.45 ± 0.98	30.62 ± 0.71k	34.12 ± 0.79f-j	34.00 ± 0.79	82.44 ± 0.93ef	82.72 ± 1.21g	81.36 ± 1.65ij
	T_7	82.64 ± 1.91fg	82.38 ± 1.80	86.19 ±1.03	32.96 ± 0.48g	35.47 ± 0.51d-h	36.36 ± 0.53	89.09 ±0.02bc	89.94 ± 1.06d	93.29 ± 0.25bc
	T_8	78.19 ± 1.13i	84.15 ± 1.85	87.34 ±1.04	32.00 ± 0.65hi	33.90 ± 0.69g-j	36.17 ± 0.73	90.50 ± 2.11b	92.41 ± 2.42cd	94.85 ± 2.21b

Contd...

Variety & Treatment		Germination (%)			Vigor index			Soluble protein content (mg/g FW)		
		2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
V_3	T_0	72.39 ± 1.25l	74.29 ± 1.78	76.58 ± 1.55	24.33 ± 0.63p	28.38 ± 0.98l	29.88 ± 0.52	77.67 ± 0.02hij	83.00 ± 0.02g	78.16 ± 0.24k
	T_1	78.69 ± 1.82i	79.06 ± 2.05	81.50 ± 1.41	28.81 ± 0.50m	33.23 ± 0.58ij	35.35 ± 0.92	79.39 ± 0.70ghi	77.46 ± 1.36kl	80.17 ± 1.17jk
	T_2	80.36 ± 1.16h	82.21 ± 1.90	84.75 ± 1.96	31.53 ± 0.64ij	37.76 ± 0.98bc	38.53 ± 0.45	80.93 ± 0.21efg	82.05 ± 1.45gh	83.04 ± 0.25hi
	T_3	82.32 ± 1.66g	84.63 ± 1.71	87.25 ± 1.26	32.24 ± 0.84h	37.67 ± 0.83bc	39.19 ± 0.79	81.25 ± 0.95efg	83.53 ± 0.98fg	81.89 ± 0.49hij
	T_4	90.67 ± 2.36a	91.58 ± 1.59	94.42 ± 1.91	35.44 ± 0.82bc	42.47 ± 0.86a	43.79 ± 1.01	81.01 ± 0.24efg	93.36 ± 1.36bc	90.80 ± 1.06def
	T_5	86.16 ± 1.00c	88.85 ± 2.05	90.67 ± 2.04	34.77 ± 0.50de	38.42 ± 1.11b	40.44 ± 0.58	89.69 ± 0.24b	90.11 ± 1.58d	92.89 ± 2.97bcd
	T_6	81.72 ± 1.89g	81.56 ± 1.88	83.39 ± 1.93	30.65 ± 0.35k	35.14 ± 0.41e-i	36.35 ± 0.42	80.00 ± 0.94fgh	79.99 ± 0.02hij	82.53 ± 0.02hi
	T_7	85.39 ± 1.73cd	85.25 ± 1.97	87.82 ± 2.03	33.18 ± 0.77g	36.01 ± 0.83c-f	37.69 ± 0.87	88.91 ± 0.27bc	91.25 ± 0.54cd	92.63 ± 0.82bcd
	T_8	84.07 ± 1.21e	83.29 ± 1.92	85.75 ± 1.98	33.90 ± 0.69f	34.32 ± 0.69f-i	38.53 ± 0.78	94.19 ± 1.65a	96.07 ± 1.68a	100.12 ± 0.59a
LS		**	NS	NS	**	**	NS	**	**	**
CV (%)		0.82	3.34	1.79	0.97	3.16	2.91	0.90	1.58	1.61

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per DMRT. V_1 = BARI wheat-28, V_2 = BARI wheat-29, V_3 = BARI wheat-30, T_0 = Control, T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *T. viride* + vermicompost + green manure, T_8 = Chemical fertilizer, DAS = Days after sowing, NS = Non-significant difference between initial and final values, LS = Level of significance, ** = 1% Level of significance, CV = Co-efficient of variation.

Chapter V
Discussion

5. DISCUSSION

This section represents the discussion of results of the investigation in relation to the effect of soil amendments on physical and chemical properties of soil, seedling sustainability, crop growth, yield and yield contributing components and seed quality of wheat through utilization of probiotic and organic manures. Throughout the research, parallel results were shown for T_8 (Chemical fertilizer) and T_4 (Poultry manure + vermicompost + green manure) with few exceptions. Chemical fertilizer can give instant results, but its long term effect is not good for crops and soil. On the contrary, organic soil amendments have many positive effects on soil and crops. Therefore, organic soil amendment has given emphasis in this finding.

5.1 Effects of soil amendments on soil properties

5.1.1 Physical properties

As a physical component, soil moisture has an important role on plant nutrient availability and uptake. At the first cropping season of study, the moisture content of the amended soil presented the negative value over initial value. Then moisture content of soil was found as an increasing trend in the next two years of study except no amendments (T_0) and with chemical fertilizer (T_8). In the study period, the maximum decrease of moisture was recorded from T_8 (-3.33%) in 2016-2017 and the maximum moisture increase was found in T_3 (+0.87%) during 2018-2019. It might be due to the effect of the nature and decomposition rate of organic matter added to the soil. As also may be due to improvement of soil physical property like aggregation of soil particles and water holding capacity as a result of organic waste applications. The findings regarding soil moisture content was also consistent with the findings of Vengadaramana and Jashothan (2012) and Desta (2015).

Bulk density is a vital factor to define the soil structure which also explains the soil quality, productivity and porosity (Almendro-Candel 2018). From this study, decrease of soil bulk density was recorded under organic inputs, added plots and increase in chemical fertilizer treated plots. Considering the initial and final value of bulk density, the higher significant deviation (-0.08 g/cc) and significant increase (+0.10 g/cc) was recorded from treatment T_3 and T_8, respectively in the last year of the study. The reason behind this result may be for the potentiality of compost in improving soil physical characteristics such as aggregation of soil particles. This statement was at par with Mbah and Onweremadu (2009) findings. Additionally, Zink and Allen (1998) also mentioned the improvement of soil aggregation through organic amendments with compost. Brown and Cotton (2011) also stated that organic fractions reduce the total weight of soil which results in minimal bulk density.

Particle density helps to understand the physical property of a soil sample which indicates presence of organic matter (Abdalmoula and Alias 2016). During the study, it has been observed that addition of organic manure decreases the particle density of soil. From the comparison of different amendment treatments, T_2 and T_3 showed the higher capability to reduce particle density (-0.02 g/cc) of soil round the study period. It may be due to higher organic matter content of manure and its impact on soil physical properties improvement. This strong association was previously notified by Celik et al. (2004) and Rasoulzadeh and Yaghoubi (2010).

Indeed, porosity is a pathway of air and water movement and residence of the root which is an essential part of soil structure (Nimmo 2004). However, the porosity of soil was increased by the application of organic amendments in this research. The highest positive change of porosity (+2.83%) was recorded from the application of T_3 and the second most (+1.82%) from T_2. It might be due the fact of addition of organic manure which increases the organic matter status of soil including particle binding agents and thus led to improved soil porosity. These results are in agreement with the findings of Kirchmann and Gerzabek (1999), Vasilica (2009) and Woignier et al. (2016). Furthermore, Marinari et al. (2000) was reported that addition of organic fertilizers and compost increased total soil porosity.

Different soil particles aggregate *viz*. sand, silt and clay form the texture of soil. Inherent soil texture may be influenced by any physical disorder but changing of soil texture needs a long time. From the analysis of soil particles, it was observed that a little change has been made over initial value through the study period. Analyzed data presented the decrease of sand and clay particles, whereas increase of silt particles by all the organic amendments and greater in treatment T_3. Such kind of variation may be due the result of organic matter addition which prohibits the dispersion of particles and helps to improve soil structure and texture. Although there was variation in particles content percentage, but soil texture remained unchanged. It may take long time to change the soil texture. But within short time, the texture can not be improved using organic matters that have been occurred in our study. It was reviewed by many researchers that organic manure improves the soil structure and texture. This finding is in line with the opinion of Cooperband (2002), Adesodun et al. (2005) and Mahmood et al. (2017).

5.1.2 Chemical properties

Soil pH that relates with soil acidity or alkalinity is an important issue for soil fertility which showed deviation from initial alkaline soil under all the treatments applied in this study. The soil pH was declined maximum (-0.10 unit) with the amendments of T_2 and T_3 after three years of study. This decline was possibly associated with the application of organic manures which may produce organic acids and pushes the change to neutral (Wakene et al. 2005). In this respect, Sumner (2009) stated that to create hospitable soil environments organic matter slow down acidification and buffer soil pH. Brautigan et al. (2014) treated the organic amendments as a means of reducing soil pH in alkaline soil.

Application of organic inputs slightly increased the organic matter content of soil over initial in the study time. The gain of organic matter may be for the cumulative action of different organic amendment inputs which were led for such increased accumulation. Here the maximum significant accumulation (+0.14%) was noted in T_3. Many researchers were stated the similar result on organic matter enhancement by adding organic manures *viz.* Pattanayak et al. (2001), Sarwar et al. (2003) and Bhogal et al. (2018). Furthermore, organic matter declining is associated with less application or less availability of organic manure, continuous cropping, removal of crop residues and excessive tillage (Ladha et al. 2004). While a sustainable cropping system with reasonable nutrient management practices might be adopted by organic amendment of soil like compost (Makinde 2007).

Except the first year, the rest two years of the study produced increments of total N by organic amendments of soil. There most pronounced (+0.013%) treatment was poultry manure + vermicompost + green manure (T_4). It might be due addition of biomass (Ali et al. 2018) and also biological nitrogen fixation capability (Bista and Dahal 2018) of the treatment component. This was also credited by adequate supply of organic matter and higher percentage of N by poultry manure. The presence of N helps microbial activity for decomposition of organic manures that residual effect was retained in the soil. This result is in line with the findings of Iqbal et al. (2008), Ogunbanjo (2010) and Omara et al. (2019).

Chemical fertilizers and organic manures are the dominant source of K input to soil. The Table 12 showed that K value was reduced at the beginning of the study by all the amendments practice, while increased in the next two cropping seasons. Among the treatments maximum increase (+0.015 cmol (+)/kg) of K was noted by poultry manure (T_4) application. There all organic amendments including chemical fertilizer were found to be a positive supplement of K to soil. This might be due to combined application of each organic amendment and recommended dose of chemical fertilizer which releases K and reduction of K fixation that retained exchangeable K. Some earlier workers mentioned the similar findings as found in the study (Bharadwaj and Omanwar 1994, Ali et al. 2009). Abubakar and Ali (2018) also evaluated the effect of poultry manure as the alternate refill of NPK.

Phosphorus (P) as a major plant nutrient acted on stem elongation and hardening, disease prevention and development of the root system which resulted in better crop growth and yield. At the end of first year of study, all the applied treatments demonstrated negative P balance over initial value. It may be due to less presence of P and higher uptake by plants. But after the first cropping season i.e. in the next two years, the presence of P reported as positive by the most applied amendments except control. Where the maximum (+5.42 µg/g) P balance was found at the second cropping season as well as in third season (+4.05 µg/g) by T_3. Such increment of P may be due to residual effect of organic manures and recommended doses of fertilizer to soil. The outcome is in harmony with the results by Shen et al. (2011).

Beside this, organic amendment with compost, cow dung and poultry manure played a vital role of retaining P in available form and improving P fertility status in soil (Reddy et al. 2000, Eckhardt et al. 2018).

Sulphur (S) is an important micro nutrient for plants. Plant growth, seed production, protein and chlorophyll content are linked with S in wheat production (Girma et al. 2005). In this study, most of the organic amendments including chemical fertilizer had the positive value in S retention in soil. Among organic amendments compost (+1.45 µg/g), cow dung (+1.11 µg/g) and poultry litter (+1.31 µg/g) showed slight enhanced values. This might be due to the reason for higher organic matter, microbial decomposition and mobilization of S derived from organic manure. Such increment of S was also reported by Paulsen (2005), Eriksen (2009), Forster et al. (2012) and Gao et al. (2017).

Zn is an essential micronutrient for wheat and organic outputs are constructive to agro-environment (Ali et al. 2019). In the study, changes of Zn exhibited negative value over initial under all the amendments during 2016-2017 cropping year. But positive change of Zn was reported by all the amendments excluding control in the sequential two years, where the treatment T_4 (+0.06 µg/g) followed by T_3 (+0.05 µg/g) added higher balance. This was detectably attributed to addition of organic manures and its efficacy to deliver micronutrients with solubilizing capacity of this nutrient (Behera et al. 2011). Furthermore, there is also some evidence for such findings presented by Antil and Singh (2007) and Ru et al. (2012).

Soluble salts concentration of growing media and ability to conduct electrical current is expressed by electrical conductivity (EC) (Schaefer et al. 2007). In this study, all amendments performed as vehicle of EC enhancer over initial but not in control. The maximum influence (+13 µs/cm) from starting (145 µs/cm) to end value (181 µs/cm) of the study was recorded by the application of poultry manure (T_4) followed by compost combination (T_3) amendment (+11 µs/cm). Such increase of EC can be occurred due the application of organic manures for soil amendment that leads water holding capacity and available selected soil nutrients with its reasonable mineralization and sorption of ions that prevail in the soil (USDA 2011). These results are in harmony with the findings of Zhao et al. (2014), Carmo et al. (2016) and Bhatt et al. (2019).

Organic manures applied in the soil need to be decomposed for release nutrients by soil microbes. The C:N ratio is varied from 8-10:1 in soil and the ratio is an indicator of nitrogen availability in soil. Microorganisms break down the applied organic manures in soil to get carbon and then release nitrogen for plants (Brown 2015). The high C:N ratio (>30) content materials may create deficiency of nitrogen to plants due slow break down of organic manures. In this study, most of the amended materials had a C:N ratio not more than 30. The data collected from the research revealed that positive balance of C:N ratio in the first year was exhibited by all treatments, but negative in the rest two years except in T_0 and T_8 (Table 17). There the lowest (8:1) and the highest (23:1) C:N ratio was noticed from T_4 and T_0, respectively. It might be due to deficiency of nitrogen in the first year and lower decomposition, but in the next two seasons higher decomposition with available nitrogen reduced the C:N ratio. Thus organic soil amendment practices directed such change of C:N ratio and that was reported by many researchers (Huang et al. 2001, Hachicha et al. 2006, Yaacob et al. 2019).

5.2 Effects of soil amendments on growth and yield of wheat

5.2.1 Seedling survivability

A significant variation of seedling infection was noticed all over the research period. The trend of infection was found to decline with the progress of the study due to application of probiotic and organic manure. The highest rate of seedling infection was found in T_0 (2.32%), while the minimum rate of infection was recorded in T_5 (0.32%) from 2018-2019. It might be due to the definite role of probiotic fortified-organic manures that exerted antagonistic effect against the fungi causing seedling infection. Furthermore, the addition of organic matter may create a hospitable environment for growth and development of fungal antagonists resulting in enhanced biocontrol activity (Sarkar et al. 2002). This finding was in harmony with the reports Tewari and Singh (2005).

Seedling infection later on converted into seedling blight. Like seedling infection, this parameter was also varied significantly under various treatments all over the study period. The control activity against seedling blight was highly observed in T_5 (0.87%) and the lowest exhibited from check in T_0 (4.74%) during 2018-2019. Such result may be obtained for the efficacy of the prohibitory and biocontrol action of the treatment. This efficacy of *Trichoderma* fortified-organic manures was evaluated to reduce the pre-emergence and post-emergence seedling mortality, diseases of stem and root of chickpea by Talukder et al. (2017). Similar control activity of *Trichoderma* spp. against plant pathogen and seedling mortality was also reported by Bhuiyan et al. (2007) and Ha (2010).

5.2.2 Leaf chlorophyll content

Chlorophyll content of leaf from diverse treatments was provided significant dissimilarities from beginning to end of the study. On the focus of organic amendments, T_4 (48.37 SPAD) next to T_8 (51.48 SPAD) had the highest accumulation of chlorophyll and the smaller was noticed in T_0 (40.33 SPAD). It may probably relate with the decomposition rate of organic manures that happened in case of T_4 treatment. This result was supported by Khan et al. (2005) with the statement that N supply in organic treatment is generally restricted and slows N mineralization as compared to crop demand of N. Chlorophyll content is closely related to the presence of N and poultry manure (T_4) had the higher ability of supplying N. This result is an agreement with the findings of Sims and Wolf (1992), Khanam et al. (2001), Ru et al. (2012) and Krishna (2013).

5.2.3 Growth attributes

The soil amendments demonstrated a remarkable significant variation on TDM at all DAS. Generally, with the advancement of time total dry matter (TDM) accumulation of wheat plants positively progressed during the research time. This progress of TDM at later stages might be used for the development of a large number of late tillers (Balyan 1992, Rahman et al. 2006) resulted in increased TDM. The accumulation of TDM was commonly exhibited the higher in T_8 (767.14 g/m^2) and it was statistically identical with T_4 (750.91 g/m^2) at 85 DAS in 2018-2019. The improvement of dry matter accumulation possibly due to high content of essential nutrients present in poultry manure which accelerates vegetative growth (Muhammad et al. 2018). This finding was also supported by Bakhtiar et al. (2017) by the statement that N in poultry manure promoted leaf, stem and spike growth which enhanced plant vegetative growth.

Leaf area index (LAI) expresses the efficacy of photosynthetic processes which is related with crop vegetative growth as also crop yield. The leaf area had an ascending tendency up to 55 DAS, whereas descending nature exhibited in the next 70 to 85 DAS during the three years of experiment. At the last sampling date, T_8 (3.73) and T_4 (3.39) showed the statistical identical value of LAI and a similar tendency was observed in the consecutive year 2017-2018. It might be due to slow and continuous release of plant nutrients from organic manures which directed more leaf production resulting in increased leaf area. Ogundare et al. (2012) and Kareem et al. (2017) confirmed the judgments of the research outcome. Furthermore, Al-Rawashdeh and Abdel-Ghani (2008) supported the decline of leaf area index due to losses of nitrogen (gaseous form) at the end of vegetative stage.

Generally, crop growth rate (CGR) was demonstrated lower increase at the initial stage of wheat growth and later it reached the peak at 55-70 DAS and then declined. Most of the sampling dates revealed that T_8 had the highest activity in CGR followed by T_4 but at the end of CGR sampling (70-85 DAS) T_4 showed the greater influence. Thus, the greater CGR value 21.24 $g/m^2/d$ was followed by 19.89 $g/m^2/d$ in T_8 and T_4, respectively. This slow-fast-slow growth rate trend might be due to the slow availability of nutrients that produced less dry matter at the early stage with poultry manure and later stage produced more dry matter almost similar to chemical fertilizer for releasing more nutrients. This observation may be linked with the findings of Geng et al. (2019). Afterwards the decrease of CGR was noticed due to leaf senescence and tiller drying. This result is an agreement with the observation of Boateng et al. (2006) and Ram (2017).

5.2.4 Yield and yield contributing attributes

Throughout the research duration, T_8 and T_4 showed the greater influence on plant height. During the study, the maximum (93.81 cm) and closely the next higher (91.29 cm) plant height was noticed from T_8 and T_4, respectively. It might be due to rich and balanced nutrients (N, P, K, Ca and Mg) and least C:N of poultry manure which encouraged quick nutrient uptake and sustainable performance. Furthermore, Rehman et al. (2010) stated that organic manure increases plant cell division which results in taller plant production. These findings are in line with the results of Umanah et al. (2003), Gowda et al. (2010) and Shahid et al. (2015).

The parameter plant/m^2 is one of the major vegetative growth indicators of wheat. The best values of plant/m^2 were obtained from T_8 (216.11) and then T_4 (202.81) where the lowest at T_0 (158.66). The ability of such enhancement plant/m^2 due to application of poultry manure might contain high amounts of nutrients and organic matter that improved the soil structure and environment which aids density of plant. Result in the study was in the same manner previously notified by Hassan (2002), Dauda et al. (2008) and Ismaeil et al. (2012).

Tillering is one of the important growth stages of wheat which provides the necessary stalks for satisfactory production. Tiller number and its survival may be influenced by weather and soil nutrient status. A gradual advancement of tillering was observed under the soil amendments and significantly higher in T_8 (4.13) and T_4 (3.84). This result is in agreement with the findings of Enujeke (2013) who reported that readily available and easily absorbable nutrients lead to faster growth and development and ultimately to more tillers by application of poultry manure. Besides this, addition of organic matter improved the soil physical condition which influenced the tillering. This result is in accordance with the observation of Bhuiya and Akhand (1983) and Rajput et al. (1988). Though tillers are lateral branches which emerge from the main stem, but not all produce an ear. Generally, the first two-three tillers are noted as productive tillers of wheat and production is related to environment and nutrition supply. In this investigation, a greater number of productive tiller/plant was demonstrated in T_8 (3.89) and T_4 (3.69). This advancement of effective tiller might be due to optimum moisture and available nutrients provided by poultry manure which may have created the favorable condition for wheat growth. This was supported by Simpson (1990), Eck and Stewart (1995), Mitchell and Tu (2005) and Sistani et al. (2008). The result of this investigation was related to the observations of Belefant-Miller (2007), Abbasi and Khaliq (2016).

The long typically needle like appendage of the lemma in spikelet in wheat known as awn. It has relation to photosynthesis and improvement of grain yield and quality (Elbaum et al. 2007, Yuo et al. 2012). Applied treatments as a source of variance significantly influenced the awn length of wheat. Among the treatments, T_8 produced the higher awn length (7.38 cm) and it was statistically at par with T_4 (7.27 cm), whereas the lowest in T_0 (5.36 cm). It might be due to creating soil healthier and nutrient restore for vegetative as well reproductive growth of wheat which was obtained by soil amendment. This finding is partially related in accordance with the observation of Kowsar et al. (2015).

Data regarding spike length was affected significantly by various soil amendments round the research seasons. Results showed that among the treatments, T_8 was produced the utmost spike length (8.60 cm) and then T_4 exhibited the nearer one (8.43 cm) and it was statistically at par with T_8. It might be due to higher nutrient reserve and moisture retention capacity of poultry manure than other organic manures. This result is correlated with Hussain (2001) and Ahmed et al. (2002). Nevertheless, green manure fortified poultry manure keeps the N balance which enhances the length of spike of wheat. The above statement was also supported by Nguyen et al. (1995).

Spike properties no doughty affect the grain yield. Spikelet/spike treated as an important element of wheat grain yield (Sabaghina et al. 2014). Spikelet/spike in this study revealed variation between 13.80 (T_0) to 17.97 (T_8). These variations are in line with Tahir et al. (2011) and Sarwar et al. (2007) who reported that yield components of wheat significantly influenced organic manures over control. Considering the mean values of spikelet/spike to evaluate the performance of different treatments, the maximum value (17.97) was observed in T_8 and it was statistically identical with T_4 (17.81) all over the research period. It might be due to supply of nitrogen rich organic manures which positively affected the growth and yield attributes of wheat. These findings are partially correlated with the observation of Siavoshi et al. (2011). With the acceptance of the above assumption of N supply, especially during spikelet differentiation and development, T_8 produced the higher fertile spikelet/spike (17.24) and T_4 (17.00) having statistical equality. Similar observations were made by Patel et al. (1995) and Rahman (2004).

Grains/spike is a common yield component for cereals (Slafer et al. 1996, Thiry et al. 2002). Under this experiment the tendency of grains/spike was notified higher from T_8 which was followed by T_4. These two treatments were shown to have the greater value 45.73 and 44.40 with significant variation compared with the rest of the treatments. Considering the organic amendment, presence of greater N in poultry manure produced more dry matter and partitioning it towards grains which enhanced the grains/spike. This result is confirmatory with the outcomes of Shah et al. (2010), Yildirim et al. (2016) and Mukhtiar et al. (2018).

As a yield component, grains weight/spike of wheat was measured and analyzed by some researchers (Frederick et al. 2001, Peltonen-Sainio et al. 2007). Application of different soil amendment treatment significantly affected the grains weight/spike over the study period. Data across various amendments demonstrated that the maximum weight of grains/spike was noticed in T_8 (2.20 g) afterwards in T_4 (2.14 g), while the least in T_0 (1.60 g). The advancement of grain weight/spike from organic manures treated with poultry manure that may have the balanced nutrient stock during the grain filling stage. Similar reports were also presented by Sevaram et al. (1998), Garg and Bahla (2008).

For cereal crops, 1000-grain weight is an important trait to determine the yield and yield attributes (Metho et al. 1998). The data concerning 1000-grain weight of wheat clearly indicated that the applied treatments T_8 (54.12 g) and T_4 (53.90 g) significantly increased the weight than others. The reason for such kind of nearer advancement by T_4 (poultry manure) may be due to availability of nutrients throughout the growing season and improvement of soil characters. This outcome was agreed with Ma et al. (1999), Haris et al. (2002) and Ahmed et al. (2017).

Different major yield components like spike/m^2, number and weight of grains/spike and 1000-grain weight mathematically functioned on yield of cereal crop (Thiry et al. 2002). All the soil amendments proved its significant effect on grain yield of wheat. From the mean comparison of different treatments it notified that the maximum grain yield was noted for T_8 (4.25 t/ha) followed by T_4 (4.09 t/ha) and the minimum of it (2.36 t/ha) belonged to T_0. The production of yield by T_4 may be for the reasons of enhancement soil fertility and improvement of physical conditions, reduction of nutrient losses and preservation of soil biota which contributes to higher grain yield. This result is in conformity with the observation of Sharma and Madan (1988), Shanggan et al. (2000), Khaliq et al. (2004), Islam et al. (2009), Naseri et al. (2010) and Zhang et al. (2016).

Wheat straw yield was responded significantly from the application of various soil amendmentsover the research period. The maximum straw yield (5.40 t/ha) was produced by chemical fertilizer (T_8) and the nearest result (5.31 t/ha) was obtained by poultry manure (T_4). This performance of organic manures might be due to capability of abundant nutrients supply and creation of a favorable growth environment. This turn on increased photosynthetic activity, cell elongation and vegetative growth that was reflected in straw yield. Similar cause and effect was also noted by Auti et al. (1999), Usman et al. (2003), Akhtar et al. (2011), Kumar and Abraham (2018).

Harvest index is an important reproductive efficiency of crops in increasing grain yield. In the present study, the harvest index of wheat was significantly affected by the various soil amendments. Regarding this parameter, the highest value (44.05%) was recorded with the application of treatment T_8 followed by T_4 (43.48%), whereas the least value (36.13%) was obtained from T_0. The performance of poultry manure on boosting harvest index might be continued supply of nutrients and higher dry matter distribution towards grain. This result is in agreement with the investigation of Swarup and Yaduvanshi (2000), Rees and Castle (2002), Krishnan et al. (2003), Delfine et al. (2005), Kabesh et al. (2009) and Khan et al. (2018).

5.2.5 Seed quality

Introducing designed soil amendments not only developed growth and yield of wheat but also enriched the parameters of seed quality. Significantly greater mean of seed germination was noticed in T_4 (92.08%), whereas the least mean was calculated from T_0 (74.78%). This might be due to adequate supply of nutrients which helped to build up carbohydrate like seed elements thus producing vigorous seeds. The outcome of the investigation is the conformity of previous results of researchers Gowda et al. (2010), Aslam et al. (2011), Raissi et al. (2012) and Peerzada et al. (2016).

Vigor index is an imperative quality of seed that indicates the potentiality of constant emergence of seedlings (Pradeep 2018). In the present study, it was observed that soil amendments effectively increased vigor index of seed over control. This upturn was dominantly (41.54) found from the plot which consumed poultry manure (T_4), while the minimum (24.70) was found at control plot (T_0). The speed of germination i.e. vigor index might be significantly differ for providing the substantial macro and micro nutrient in the grain filling stage and stored in seed. This result is in agreement with the reflection of several researchers like Page-Dumroese et al. (1991), Farhad et al. (2011) and Sheoran et al. (2017).

Among the major cereals, wheat is the prominent source of vegetal protein (13%). Protein content in wheat seed showed the variable responses to different soil amendments where finally T_8 produced greater total soluble protein (96.43 mg/g FW) followed by T_4 (92.56 mg/g FW) and the least at T_0 (79.10 mg/g FW). One important part of the study is organic amendment of soil therefore; special emphasis had been given in this case. The increased protein content might be due to availability of high NPK that satisfy the plant requirement. The accumulated N in the leaf mobilized to seed components which leads the protein production. This result is in pact with the findings of Abedi et al. (2010) and Rasul et al. (2015). Moreover, the improvement of protein content might be also due to green manure based crop rotation and poultry manure application which enriched N availability and N uptake by wheat plant. Related findings are reflected by Alam et al. (2018).

Chapter VI
Summary

6. SUMMARY

The study was carried out for three consecutive years 2016-2017, 2017-2018 and 2018-2019, with a view to find out the effect of probiotic and organic soil amendment on sustainable improvement of wheat (*Triticum aestivum* L.) growth and yield. The experiment was laid out in randomized complete block design (RCBD) with three replications where three wheat varieties *viz.* BARI wheat-28, BARI wheat-29 and BARI wheat-30 and nine soil amendments *viz.* T_0 = Control (without treatment), T_1 = Rice straw + vermicompost + green manure, T_2 = Cow dung + vermicompost + green manure, T_3 = Compost + vermicompost + green manure, T_4 = Poultry manure + vermicompost + green manure, T_5 = *Trichoderma harzianum* + vermicompost + green manure, T_6 = Mung bean residue + vermicompost + green manure, T_7 = *Trichoderma viride* + vermicompost + green manure and T_8 = Chemical fertilizer (recommended dose) were used. The plant growth parameters, yield and yield contributing attributes and seed quality of wheat were studied in the research. Besides these, soil properties in respect of physical and chemical characters were also considered.

From the investigation, it has been found that moisture content of soil was greatly influenced by different amendment practices. There negative moisture balance was also found by all the amendments and -2.50% was the highest deviation occured by treatment T_7 during 2016-2017. After two years, maximum balance of moisture of soil was recorded in T_3. Two closely related physical properties *viz*. bulk density and particle density showed negative changes under different amendments round the research period, but it was positive in case of control. The higher change in bulk density (-0.08 g/cc) and particle density (-0.02 g/cc) was noticed in T_3. Based on the value of bulk density and particle density, the estimated porosity of soil also exhibited significantly better results (+2.83%) found in T_3 treatment. Though texture is a stable property of soil, but it may be changed by disruption of soil particles over a long period. Hence, no change was recorded in texture from initial to final study period but changes were recorded in respect of sand, silt and clay particles. Thus at the end of the study, the maximum significant deviation of sand (-2.33%)

was recorded in T_3 and equally value (-0.67%) deviation for clay particles was found by the T_4, T_1 and T_6. Whereas significant increase (+2.67%) of silt particles was recorded by T_3 amendment.

Inclusion of different organic amendments did not significantly influence the soil pH in comparison with initial reading. But increasing numerically trends were observed in case of T_0, T_4 and T_8, while the higher decreased reading was -0.10 unit and that was observed in T_3 and T_2. Applied amendments exhibited the building up trend of organic matter content in the experimental plots except control and the maximum accumulation (+0.14%) was noticed in T_3. Plants macronutrients like total N, available P, exchangeable K and available S were influenced positively by addition of amendment materials except control. There was significantly higher value for total N (+0.013%) and exchangeable K (+0.015 cmol (+)/kg) presented in T_4. On the other hand, under amendment with T_3, available P and available S revealed the higher value as +5.42 and +1.45 µg/g, separately. In this study, secondary nutrients of plants like Zn significantly showed the positive enhancement at the end year of cropping except control. There the T_4 was presented the greater balance (+0.06 µg/g) of Zn in comparison with other amendments. In respect of electrical conductivity of soil, it was found to be increased over initial value by organic amendments. The most pronounced value (+13 µs/cm) of electrical conductivity was obtained in T_4. Although the carbon nitrogen ratio presented a positive balance in the starting year but it was found as negative balance in the next two years. At the end year of the study, C:N ratio was observed as higher decline (-0.60) in T_4.

The results revealed that seedling survivability against seedling infection and seedling blight were higher in the V_3 than that of other two varieties in 2017-2018. The survivability of seedling was found greater under the T_5 than other organic soil amendment treatments in the season 2018-2019. The result indicated significantly lower seedling infection and seedling blight. The combination of V_3T_5 exhibited better performance for reducing seedling infection and seedling blight during 2018-2019. In the context of leaf chlorophyll content, V_3 showed greater achievement than other varieties in 2018-2019.

Among the organic amendment treatments, T_4 provided more leaf chlorophyll content, especially at the last cropping of the study. Thus the interaction of variety and soil amendments produced insignificantly the greater leaf chlorophyll from the arrangement in V_3T_4 from 2018-2019.

Growth attributes of wheat like total dry matter, leaf area index and crop growth rate were significantly affected by the selected variety. General progressive increase of TDM was recorded at all sampling dates, but the greater TDM was noticed at 85 DAS in V_3 from 2018-2019. The leaf area index and crop growth rate increased up to 55 DAS and then decreased where the V_3 produced the maximum LAI and CGR during 2018-2019. These parameters were found significantly better by the application of various organic soil amendments round the research period, however, the performance was pronounced in T_4 from 2018-2019. Though no significant variation was recorded on the maximum TDM production from the combination V_3T_4 in the season 2018-2019, but the LAI and CGR was significantly influenced by the combination and reached the peak of increase at the last year of the study.

Excluding the year 2017-2018, plant height of wheat at harvest significantly affected by the varietal influence where V_3 showed better height round the research period. Other plant characters of wheat like total plant/m^2, total tiller/plant and effective tiller/plant also provided the maximum efficiency derived in V_3 during 2018-2019. Among the treatment sets of organic amendments, poultry manure (T_4) demonstrated the best output in relation to the aforesaid parameters in 2018-2019. Furthermore, the combination of variety factor and treatment factor did not affect the above stated parameters significantly, but V_3T_4 prearrangement exposed the greater numerical value all over the research seasons.

All the spike characters as awn length, spike length, spikelet/spike and fertile spikelet/ spike were significantly influenced by varietal factors. Among the wheat varieties, V_3 was superior against the aforesaid spike characters from the first year to last year of the research. On the other hand, T_8 and T_4 showed statistically similar performance in relation to the above spike morphology in the three seasons of the study. But the organic soil amendment T_4 denoted as the best performer with higher values for the mentioned parameters in the period 2018-2019. The selected variety coupled with designated soil amendments had no significant variation on the spike parameters. But from the combination of variety and organic treatments, the combination of V_3T_4 gave the greater numerical results on these spike characters in the year 2018-2019.

Some grain related parameters like grains/spike, grain weight/spike and 1000-grain weight significantly achieved the higher value with V_3 but deformed grains/spike was high with V_1. In general, under the organic amendment treatment, T_4 significantly enhanced the grain parameters except deformed grains/spike by T_0 during 2018-2019. These parameters were found significantly higher in V_3T_4 arrangement excluding deformed grains/spike at V_3T_0.

The result exposed that variety had a significant effect on grain yield, straw yield and harvest index of wheat. The above mentioned sequential parameters recorded with the best values as 3.59 t/ha, 4.96 t/ha and 41.74% under V_3 in 2018-2019. All the soil amendment packages also significantly promoted the grain yield, straw yield and harvest index. It appeared that the expressed parameters were greatly influenced by the T_4 in comparison with the organic components of amendment. The major improvement was notified under T_4 regarding grain yield (4.09 t/ha), straw yield (5.31 t/ha) and harvest index (43.48%) in 2018-2019. This development of the yield was approximately 73%, 27% and 20% more over respective control. Due to conjunctive use of variety and organic amendment treatments, the highest grain yield (4.14 t/ha), straw yield (5.37 t/ha) and harvest index (43.91%) were produced by the arrangement $V_3T_{4,}$ V_2T_4 and V_3T_4, respectively.

The seed quality parameters such as germination percentage, vigor index and total soluble protein content were positively increased. These parameters significantly affected the varietal performance where V_3 treated as the higher producer of germination, vigor index and protein content in 2018-2019. All the treatments of soil amendment significantly influenced the above mentioned seed quality. There was a considerable higher performance noticed by T_4 for all the seed quality parameters studied in this research. The relationship of variety and soil amendments showed non-significant movement in case of germination and vigor index, whereas significant progress was found in protein content at the final year of study. These relations were higher in case of germination and vigor index in V_3T_4, but the protein content showed better in V_2T_4.

The experiment has made known that the application of probiotic and various organic manures improved the soil physical and chemical properties. In this investigation, manure acted as a vital source of organic matter and essential plant nutrients reservoir which influenced the physical characters of soil like moisture, particle density, bulk density and porosity as also build up positive changes in chemical properties like pH, C:N ratio and electrical conductivity of soil as well as plant growth. The above mentioned characters were efficiently modified by the application of green manure and vermicompost fortified poultry manure (T_4). Hence for improvement and sustenance of soil fertility, poultry manure may be considered as an imperative component.

There was a potentiality for sustainable improvement of wheat growth, yield and seed quality with soil amendment through probiotic and organic manures. In that term, inclusion of green manure, vermicompost and poultry manure may be a worthy alternative against chemical fertilizers. The capacity of surprising decomposition and nutrient release of those organic manures could be used to synchronize the nutrient demand of wheat. Organic manures particularly poultry manure was a healthier source for improvement of growth, yield and seed quality of wheat as compared to other manures.

Thus the organic manures i.e. poultry manure combination (T_4) would be an important substitute of chemical fertilizer for its easy availability, less cost, positive residual effects and soil fertility storage that directed to sustainable environmental improvement. So, the above declared manures may be suggested to use for soil amendment and sustaiable wheat production in the studied region.

Chapter VII

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Appendices

APPENDICES

Table 1: Scenario of soil organic matter depletion during 20 years in different Agro-Ecological Zones of Bangladesh.

Name of AEZ	Land type	Organic matter (g/kg) (Average)		Total depletion of organic matter (%)
		1969-1970	1989-1990	
1. Madhupur Tract	Highland	17.8 (13-24)	12 (6-17)	32.58
2. Barind Tract	Highland & MHL	14.5 (10.6-20)	11.5 (9-14)	20.69
3. Old Himalayan Piedmont Plain	Highland	13.2 (10-16.5)	12 (8-15)	9.0
4. Tista Meander Floodplain	Highland & MHL	15.5 (14.6-16)	12.3 (10-15)	20.6
5. Northern and Eastern Hills	Highland & MHL	20.4 (14.9-24.6)	13.2 (10-15)	35.3
6. Old Meghna Estuarine Floodplain	Highland	21.6 (19.2-26.1)	11.7 (10-15)	45.8
7. High Ganges River Floodplain	Highland	12.1 (6.4-16.1)	9.8 (3-14)	19.0
8. Old Brahmaputra Floodplain	MHL land	15.6 (10.9-21.6)	12.3 (9-15)	21.15

Source: Mia et al. (1993), MHL = Medium High Land.

Table 2: Emergence of new nutrient deficiency with time in soil.

Nutrients								
								?
							Mg	Mg
						B	B	B
					Zn	Zn	Zn	Zn
				S	S	S	S	S
			K	K	K	K	K	K
		P	P	P	P	P	P	P
	N	N	N	N	N	N	N	N
Year	1951	1957	1960	1980	1982	1995	2000	2010

Source: Jahiruddin and Satter (2010).

Table 3: Nutrient elements content in different organic manures.

Organic matter	N (%)	P (%)	K (%)	S (%)	Zn (%)
Green manure	0.70	0.40	0.38	0.20	-
Rice straw	0.50	0.08	1.60	0.09	0.01
Cow dung	1.20	0.80	1.30	0.13	0.01
Compost	1.80	0.25	0.94	0.20	0.02
Vermicompost	1.75	1.00	0.75	0.03	0.02
Poultry manure	1.85	0.60	0.76	0.06	0.05

Analysed at Soil Resource Development Institute (SRDI) Laboratory, Shyampur, Rajshahi, Bangladesh.

Table 4: Monthly minimum, maximum and average air temperature (°C), rainfall (mm) and relative humidity (%) during the experimental period are given below:

Year	Month	*Temperature (°C)			*Humidity (%)			**Rainfall	*Sunshine
		Max.	Min.	Average	6.0 am	6.0 pm	Average	(mm)	(hours)
2016	September	34.04	26.35	30.20	96.87	86.20	91.53	157.20	5.03
	October	33.07	23.92	28.50	96.97	83.48	90.23	94.60	7.73
	November	29.99	17.52	23.76	96.67	82.53	89.60	0.00	6.62
	December	26.15	13.65	19.90	97.87	83.45	90.66	0.00	4.49
2017	January	25.18	11.02	18.10	94.35	72.84	83.60	2.20	5.73
	February	28.74	13.50	21.12	95.25	60.93	78.09	0.00	6.34
	March	31.29	18.52	24.91	93.74	62.29	78.02	43.50	6.37
	April	35.06	23.24	29.15	92.47	63.57	78.02	102.00	6.14
	September	33.93	26.59	30.26	97.37	86.77	92.07	133.40	4.02
	October	31.81	24.38	28.09	97.55	87.68	92.61	237.50	5.98
	November	29.35	17.44	23.40	96.83	83.73	90.28	5.20	7.33
	December	26.18	14.64	20.41	96.70	84.58	90.64	19.60	6.06
2018	January	22.49	8.50	15.50	98.26	77.97	88.12	0.00	5.79
	February	28.90	14.20	21.55	96.10	65.40	80.75	12.60	5.50
	March	34.02	19.05	26.54	93.03	51.35	72.19	8.60	7.99
	April	34.13	22.21	28.17	93.16	66.16	79.66	142.50	7.68
	September	34.32	26.12	30.22	96.80	82.47	89.63	117.80	6.18
	October	32.11	21.84	26.98	95.35	83.00	89.18	85.80	7.23
	November	29.99	16.73	23.36	97.33	82.60	89.97	0.00	7.52
	December	25.27	11.64	18.45	94.94	79.61	87.27	17.20	6.41
2019	January	25.46	10.23	17.84	94.65	73.29	83.97	0.00	7.37
	February	27.62	13.17	20.40	95.36	65.29	80.32	47.20	7.63
	March	32.08	17.45	24.77	95.42	53.03	74.23	68.00	7.84
	April	34.52	22.95	28.74	94.27	64.87	79.59	113.90	7.16

*= Monthly average **= Monthly total.

Source: First class Meteorogical Observatory, Shyampur, Rajshahi, Bangladesh.

List of Publications and Abstract

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EFFECTS OF PROBIOTIC AND ORGANIC FERTILIZERS AS SOIL AMENDMENTS ON THE GROWTH AND YIELD OF WHEAT

Md. Anwar Hossain[1,2], Md. Mahmodol Hasan[3], Md. Belal Hossain[3] and S.M. Shahinul Islam[1]*

[1]*Plant Biotechnology and Genetic Engineering Laboratory, Institute of Biological Sciences,*
[3]*Plant Pathology Laboratory, Agronomy and Agricultural Extension Department,*
University of Rajshahi, Rajshahi - 6205 (Bangladesh)
[2]*Directorate of Secondary and Higher Education, Dhaka - 1000 (Bangladesh)*
*e-mail: *shahinul68@gmail.com*

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ABSTRACT

Present study aimed to comprehensively assess the impact of organic amendments on crop health without compromising on growth and yield. To evaluate the effect of organic amendment a comprehensive study in wheat was conducted in a randomized complete block design with three replications for three consecutive wheat growing seasons (2017-2019). The experiment comprised of was nine soil amendment treatments wherein organic manures, probiotics and chemical fertilizer were used. The dry matter accumulation, leaf area index, and crop growth rate were assessed at 25, 40, 55, 70 and 85 days after sowing (DAS). At 85 DAS, the maximum TDM accumulation (769.89 g m^{-2}) was recorded by the chemical fertilizer which was statically similar (752.48 g m^{-2}) with poultry manure + vermicompost + green manure (*Sesbania rostrata*). Similar trend was found in case of LAI (4.07 followed by 3.84) at 55 DAS. Likewise, the maximum CGR 20.30 and 19.07 g m^{-2} d^{-1} was noted at 55-70 DAS under the same treatment condition. The study revealed that the growth attributes significantly increased in chemical fertilizer than poultry manure + vermicompost + green manure treatment and untreated control. Application of probiotic and organic manures significantly influenced the growth attributes of wheat. The information generated is very useful for farmers and agriculturist for enhancing the growth and yield of wheat.

Keywords: Green and poultry manure, growth attributes, probiotics, vermicompost, yield, wheat

INTRODUCTION

Wheat (*Triticum aestivum* L.) has long been a highly popular cereal crop all over the world including Bangladesh. It is recognized as a pioneer source of protein for human consumption than other cereals. The major composition of wheat includes 66.0-71.6% carbohydrates, 13-16.7% protein, 2.5-3.1% fats and 2.5-3% crude fiber (Khan, 1984). Nearly 50% world grain production is occupied by wheat (Banglapedia, 2014; Haydar *et al*., 2020). Bangladesh possesses 31st positions rank among wheat growing countries in the world. In Bangladesh, wheat crop occupies 4% of the total cropped area, 11% of area cropped in *rabi* and contributes 7% to the total output of food cereals (Anonymous, 2008).

Bangladesh is known as a rapidly increasing populated country and thus land under cultivation is decreased to provide their accommodation. To keep harmony with increased population intensive cultivation of wheat and other cereal crops like barley, maize, rye, etc. and its cultivated lands were affected by using many chemicals and fertilizers that directly affects to food security (Haque and Islam, 2018). The long-term application of excess inorganic fertilizer or poor fertilization practice results in soil acidification and nutrient depletion, besides deteriorating the soil and environmental health (Liebig *et al.*, 2002). Further, synthetic fertilizers are chemical in natures that are harmful human, animals and environments. It has been reported that initial period of three years organic farming could give equal or more yields as compared to chemical use alone (Ramesh *et al.*, 2005). To create a favorable crop growth environment and sustainable production, organic farming may be an alternative way without using chemical fertilizers in the soil (Kshirsagar, 2008) and it may contribute to increase 80% of the yield the developing countries (Badgley *et al.*, 2007). Probitic i.e. *Trichoderma* is a common symbiont of plant root system (Vinale *et al.*, 2012) which is used as biocontrol agent and plant growth enhancer (Talukder *et al.*, 2017). Organic manures mainly poultry manure accelerates vegetative growth reported by Rasul *et al.* (2015) and Abubakar and Ali (2018). So, for achieving better crop yield and growth and retaining sound soil health, the use of high yielding varieties along with organic amendments are considered important. Hence, in view of above, a study was undertaken to assess the impact of probiotic and organic manure on wheat growth and yield.

MATERIALS AND METHODS

Preparation of soil and plant growth

The present research work was carried out in the experimental field and in the Laboratory of Plant Biotechnology & Genetic Engineering, Institute of Biological Sciences and Plant Pathology Lab., Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh during July 2016 to June 2019. The experimental field geographically was situated at 24°17` N latitude and 88°28` E longitude at an elevation of 20 m masl and belonged to the Agro-Ecological Zone-11 (AEZ-11). The soil of experimental field was poorly drained with moderately permeability, loam and slightly alkaline (pH, 8.1). The experimental soil had moisture content 19.4%, particle density 2.65 g cc^{-1}, bulk density 1.27 g cc^{-1} and porosity 51.34%. Further, the soil had organic matter content of 1.2%, K 0.150 cmol (+) kg^{-1}, total N 0.07%, P 26.30 µg g^{-1}, S 12.50 µg g^{-1}, Zn 0.75 µg g^{-1} and EC 145 µs cm^{-1} with C: N of 10:1.

Experimental design and treatments

The experiment was laid out in a randomized complete block design with three replications. The treatments comprised of three wheat varieties *viz.*, 'BARI Wheat-28', 'BARI Wheat-29' and 'BARI Wheat-30' [Bangladesh Agricultural Research Institute, Joydebpur, Gazipur] and nine soil amendments [control, rice straw + vermicompost + green manure, cow dung + vermicompost + green manure, compost + vermicompost + green manure, poultry manure + vermicompost + green manure, *Trichoderma harzianum* + vermicompost + green manure, mung bean straw + vermicompost + green manure, *T. viride* + vermicompost + green manure, and chemical fertilizer]. The unit plot size was 5.0 m^2 having a plot to plot 0.5 m, bed to bed 0.25 cm distance and 1 m from the surrounding boundary. The total unit plot was 81. Crop residues (rice straw and mung bean straw), cow dung, compost and poultry litter were applied at the rate 10 t ha^{-1} 7 days prior to sowing [BARI, 2014]. Vermicompost was applied 5 t ha^{-1} and *Trichoderma* spp. suspension (1×10^6 cfu g^{-1} @ 5 kg ha^1) before sowing. In case of chemical treatment, one third of urea (200 kg ha^{-1}), triple super phosphate 160 kg ha^{-1}, muriate of potash 45 kg ha^{-1} and gypsum 115 kg ha^{-1} were applied as basal dose (BARI, 2014). Rest urea was applied in two installments, one at 21 days after sowing (DAS) and another at 55 DAS. Crop residues were collected from the research field of IBSc, RU. Cow dung and compost were collected from a trained farmers pit under DAE Bagatipara, Natore. Poultry litter was collected from a poultry farm. Vermicompost was collected from Sumi Seed Vander, Rajshahi. *Trichoderma* spp. were cultured in Plant Pathology Laboratory, Department of Agronomy & Agriculture Extension, University of Rajshahi, Rajshahi, Bangladesh. The collected organic manures contained NPK as green manure (N 0.70%, P 0.40% and K 0.38%), rice straw (N 0.50%, P 0.08% and K 1.60%), cow dung (N 1.20%, P 0.80% and K 1.30%), compost (N 1.80%, P 0.25% and K 0.94%), vermicompost (N 1.75%, P 1.00% and K 0.75%) and poultry manure (N 1.85%, P 0.60% and K 0.76%) were used respectively.

Data collection on growth attributes

Total dry matter (TDM): For TDM, five plants were collected at 25, 40, 55, 70 and 85 DAS from each plot and sundried before the collected samples were packed individually in a labeled brown paper bag and dried in an oven at 70-80°C for 72 h till constant weight was attained.

Leaf area index (LAI): For LAI determination, five plants were collected from each plot at 25, 40, 55, 70 and 85 DAS. At each time period, the collected plants were separated into leaf, stem and spike (when appeared) and leaf area was measured by disc method (Radford, 1967). For this, every leaf was segmented into three portion and middle portion length and breadth of each leaf were measured. Among the total leaves of a plant, each leaf was packed individually in a labeled brown paper bag and placed in an oven at 70-80°C for 72 h. The leaf area was measured and calculated by using the formula:

$$\text{Area of leaf} = \frac{\text{Weight of leaves} \times \text{Area of segments}}{\text{Weight of segments}} \times \text{cm}^2$$

As growth and physiological parameters leaf area index (LAI) and crop growth rate (CGR) were calculated by using standard formulae (Radford, 1967).

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Crop growth rate (CGR): The crop growth rate was calculated from total dry matter in respect of sampling dates using the formulae (Radford, 1967):

$$\text{Crop groth rate (CGR)} = \frac{(W2-W1)}{(t2-t1)} \times \text{g m}^{-2}\text{d}^{-1}$$

Where, W_2 and W_1 are the total dry weight plant at different DAS and t_2 and t_1 are the harvest time of total dry weight at the latter and former, respectively.

Statistical analysis

The data were compiled and tabulated for statistical analysis. The data was analyzed using analysis of variance and Duncan's multiple range tests through r-studio by the "Agricolae" package.

RESULTS AND DISCUSSION

The study revealed that the chemical fertilizer and combination of poultry manure + vermicompost + green manure (*Sesbania rostrata*) showed parallel results regarding total dry matter (TDM), leaf area index (LAI) and crop growth rate (CGR) with few exceptions.

Total dry matter

The study was planned to investigate the effects of different organic manures as soil amendment on TDM accumulation of wheat at 25, 40, 55, 70 and 85 DAS (Table 1). The soil amendments showed significant variations in TDM production. Three years pooled data revealed that TDM accumulation at 25 DAS was highest (30.7 g m^{-2}) due to the application of chemical fertilizer followed by poultry manure + vermicompost + green manure (28.5 g m^{-2}), while untreated control gave the lowest value (18.0 g m^{-2}). The maximum TDM accumulation at 40, 55 and 70 DAS were recorded from chemical fertilizer (102.4, 227.9 and 533.3 g m^{-2}) and minimum in untreated control (51.8, 136.1 and 363.1 g m^{-2}). At the peak (85 DAS) of TDM accumulation, the most statistical identity was found between chemical fertilizer (769.9 g m^{-2}) and poultry manure + vermicompost + green manure (752.5 g m^{-2}). Poultry manure-based treatment, in general followed a pattern similar to that of chemical fertilizer treatment for TDM accumulation. Generally, with the advancement of time the TDM accumulation of wheat positively increased. This increment of TDM might be for creating a favourable environment for plant growth activities employed by probiotic and organic amendments of soil (Ahmad *et al.*, 2008). Such increment of TDM might be found for the development of a large number of late tillers (Balyan, 1992; Rahman *et al.* 2006). The improvement of dry matter accumulation with poultry manure + vermicompost + green manure possibly due to high content of essential nutrients present in poultry manure, which accelerates vegetative growth (Muhammad *et al.* 2018). This finding is supported by Bakhtiar *et al.* (2017) who observed that N in poultry manure significantly improves leaf and stem diameter of wheat.

Table 1: Effect of probiotic and organic fertilizers for soil amendment on total dry matter (g m^{-2}) in wheat

T	TDM at 25 DAS				TDM at 40 DAS				TDM at 55 DAS				TDM at 70 DAS				TDM at 85 DAS			
	2016-2017	2017-2018	2018-2019	Mean	2016-2017	2017-2018	2018-2019	Mean	2016-2017	2017-2018	2018-2019	Mean	2016-2017	2017-2018	2018-2019	Mean	2016-2017	2017-2018	2018-2019	Mean
T_0	18.0 ± 0.6g	19.1 ± 0.6f	17.0 ± 0.6g	18.0 ± 0.6e	45.9 ± 1.2h	50.7 ± 1.0h	58.9 ± 2.0h	51.8 ± 3.8f	124.1 ± 3.1h	136.7 ± 3.6o	147.6 ± 3.9h	136.1 ± 6.8g	329.9 ± 7.4h	365.3 ± 8.0h	394.1 ± 9.2g	363.1 ± 18.6g	532.3 ± 11.0j	551.9 ± 12.2g	574.7 ± 12.6h	553.0 ± 12.2f
T_1	20.6 ± 0.4f	22.2 ± 0.5e	23.2 ± 0.5f	22.0 ± 0.8d	61.0 ± 2.0g	69.0 ± 2.1g	76.7 ± 2.7g	68.9 ± 4.5e	157.3 ± 4.8g	169.7 ± 5.3mn	181.4 ± 5.3g	169.5 ± 7.0f	383.7 ± 10.0g	403.2 ± 10.5g	433.5 ± 11.2f	406.8 ± 14.5f	585.3 ± 14.2h	601.3 ± 17.0f	620.0 ± 15.5g	602.2 ± 10.0e
T_2	21.5 ± 0.4e	23.6 ± 0.4d	24.6 ± 0.4e	23.2 ± 0.9d	73.6 ± 2.2e	80.2 ± 1.9e	87.6 ± 2.5e	80.6 ± 5.8d	175.2 ± 4.0e	192.3 ± 4.3kl	201.6 ± 4.4e	189.7 ± 7.7de	412.7 ± 10.7e	438.8 ± 9.5e	457.1 ± 10.9e	436.2 ± 12.9de	634.7 ± 13.9f	655.2 ± 15.0d	680.8 ± 14.9e	656.9 ± 13.3cd
T_3	22.8 ± 0.5d	25.2 ± 0.4c	26.6 ± 0.4d	24.9 ± 1.1c	78.5 ± 1.2d	84.5 ± 1.3d	96.9 ± 1.8d	86.7 ± 5.4c	189.1 ± 3.2c	200.4 ± 3.2ghi	211.0 ± 3.3d	200.2 ± 6.3cd	433.4 ± 7.1d	454.9 ± 7.6d	486.8 ± 9.0cd	458.3 ± 15.5cd	654.8 ± 10.8e	677.3 ± 11.2c	706.4 ± 11.3d	679.5 ± 14.9bc
T_4	26.0 ± 0.9b	29.0 ± 0.7a	30.6 ± 0.8b	28.5 ± 1.4b	86.0 ± 1.9b	93.5 ± 2.2b	108.5 ± 2.8b	96.0 ± 6.6b	199.1 ± 4.5b	218.1 ± 4.9bcd	230.0 ± 5.0b	215.7 ± 9.0b	472.1 ± 11.7b	505.0 ± 12.1b	528.4 ± 12.1b	501.8 ± 16.4b	729.7 ± 18.0b	750.9 ± 19.0a	776.8 ± 19.1b	752.5 ± 13.6a
T_5	24.0 ± 0.6 c	26.4 ± 0.5b	28.1 ± 0.7c	26.1 ± 1.2c	81.5 ± 1.5c	89.0 ± 1.7c	101.8 ± 2.3c	90.8 ± 5.9c	192.5 ± 3.6c	205.5 ± 3.8ghi	216.7 ± 3.9c	204.9 ± 7.0bc	444.6 ± 9.0c	473.5 ± 9.1c	498.5 ± 10.2c	472.2 ± 15.6c	686.8 ± 15.4c	703.0 ± 13.9b	732.3 ± 14.8c	707.4 ± 13.3b
T_6	21.3 ± 0.4e	22.7 ± 0.4e	24.3 ± 0.5e	22.8 ± 0.9d	65.0 ± 1.7f	71.7 ± 1.7f	83.9 ± 2.1f	73.5 ± 5.5e	163.2 ± 4.3f	177.6 ± 4.6m	195.5 ± 4.2f	178.8 ± 9.3ef	398.5 ± 8.3f	417.1 ± 10.0f	449.0 ± 10.3e	421.5 ± 14.7ef	609.8 ± 12.4g	631.6 ± 13.3e	664.0 ± 14.0f	635.1 ± 15.8de
T_7	23.1 ± 0.5d	25.7 ± 0.5bc	27.2 ± 0.6d	25.4 ± 1.2c	80.8 ± 1.8c	85.9 ± 1.8d	96.3 ± 2.2d	87.7 ± 4.6c	185.1 ± 3.9d	196.0 ± 4.2ijk	208.6 ± 4.3d	196.5 ± 6.8cd	438.6 ± 9.3cd	455.4 ± 10.0d	480.3 ± 10.6d	458.1 ± 12.1cd	667.1 ± 15.5d	684.4 ± 14.9c	712.3 ± 16.3d	687.9 ± 13.2bc
T_8	27.9 ± 0.9a	29.4 ± 0.8a	34.8 ± 1.4a	30.7 ± 2.1 a	92.4 ± 2.5a	96.7 ± 2.6a	118.0 ± 3.3a	102.4 ± 7.9a	215.6 ± 5.5a	225.2 ± 5.4ab	242.5 ± 6.4a	227.8 ± 7.9a	504.0 ± 4.6a	534.2 ± 13.8a	561.6 ± 14.6a	533.3 ± 16.6a	744.4 ± 20.1a	767.1 ± 21.0a	798.2 ± 22.1a	769. 9 ± 15.6a
LS	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	1.9	2.2	2.6	6.2	2.2	2.4	2.5	6.5	2.0	2.3	2.3	6.6	1.9	2.2	2.2	6.5	1.8	2.2	2.1	6.5

Each value represents the average of three replicates. In column, the mean values superscripted with similar letter(s) are statistically identical as per Duncan's Multiple Range Test. T = Treatments, T_0 = control, T_1 = rice straw + vermicompost + green manuring, T_2 = cow dung + vermicompost + green manuring, T_3 = compost + vermicompost + green manuring, T_4 = poultry manure + vermicompost + green manuring, T_5 = *T. harzianum* + vermicompost + green manuring, T_6 = mung bean straw + vermicompost + green manuring, T_7 = *T. viride* + vermicompost + green manuring, T_8 = chemical fertilizer, LS = Level of significance, **= 1% level of significance, CV = Coefficient of variation

Leaf area index (LAI)

Leaf area index expresses the efficacy of photosynthetic processes which ultimately indicates the good vegetative growth and yield. The data indicated that the positive residual effects of manures, especially poultry manure, on LAI were still evident for three growing seasons. It was observed that all the soil amendments provided significant results for LAI at every sampling date in each year of this study. The chemical fertilizer performed better performance for LAI followed by poultry manure + vermicompost + green manure in comparison to the untreated control (Table 2). The pooled data of three years study showed highest value (4.1) of LAI from chemical fertilizer and lowest LAI (2.4) was in untreated control at 55 DAS. The increment of LAI had an ascending tendency up to 55 DAS, whereas descending nature was exhibited in the next 70 and 85 DAS during the experiment. Throughout the study period chemical fertilizer and poultry manure + vermicompost + green manure exhibited almost similar results (2.5 and 2.4) at the last sampling date of LAI. Al-Rawashdeh and Abdel-Ghani (2008) supported the decline of LAI due to the losses of nitrogen (gaseous form) at the end of vegetative stage and leaf senescence. The possible reason of parallel performance of chemical fertilizer and poultry manure + vermicompost + green manure might be due to delivering more nutrients required for crop growth which were released from poultry manure combination. Continuous release of plant nutrients from organic manures which directed to plant growth and

Table 2: Effect of probiotic and organic fertilizers for soil amendment on leaf area index (LAI) in wheat

T	LAI at 25 DAS				LAI at 40 DAS				LAI at 55 DAS				LAI at 70 DAS				LAI at 85 DAS			
	2016-2017	2017-2018	2018-2019	Mean	2016-2017	2017-2018	2018-2019	Mean	2016-2017	2017-2018	2018-2019	Mean	2016-2017	2017-2018	2018-2019	Mean	2016-2017	2017-2018	2018-2019	Mean
T_0	0.2 ± 0.0j	0.3 ± 0.0i	0.2 ± 0.0i	0.2 ± 0.0i	1.2 ± 0.0f	1.4 ± 0.0i	1.3 ± 0.0i	1.3 ± 0.1g	2.1 ± 0.1i	2.5 ± 0.1i	2.5 ± 0.1i	2.4 ± 0.1g	2.0 ± 0.1e	2.2 ± 0.1g	2.3 ± 0.1i	2.1 ± 0.1h	1.4 ± 0.0f	1.5 ± 0.0e	1.6 ± 0.1i	1.5 ± 0.1g
T_1	0.2 ± 0.0h	0.3 ± 0.0h	0.3 ± 0.0h	0.3 ± 0.0h	1.3 ± 0.0e	1.6 ± 0.1e	1.6 ± 0.1h	1.5 ± 0.1f	2.3 ± 0.1h	2.7 ± 0.1h	2.8 ± 0.1h	2.6 ± 0.1fg	2.1 ± 0.1e	2.4 ± 0.1g	2.6 ± 0.1h	2.3 ± 0.2g	1.5 ± 0.0e	1.8 ± 0.1d	1.8 ± 0.1h	1.7 ± 0.1f
T_2	0.3 ± 0.0f	0.4 ± 0.0f	0.4 ± 0.0f	0.4 ± 0.0f	1.5 ± 0.1d	1.7 ± 0.1d	1.8 ± 0.1f	1.7 ± 0.1e	2.5 ± 0.1f	3.0 ± 0.1f	3.1 ± 0.1f	2.9 ± 0.2e	2.4 ± 0.1d	2.8 ± 0.1e	2.9 ± 0.1f	2.7 ± 0.2e	1.6 ± 0.0d	1.9 ± 0.1d	2.2 ± 0.1f	1.9 ± 0.2e
T_3	0.4 ± 0.0e	0.5 ± 0.0e	0.5 ± 0.0e	0.5 ± 0.0e	1.7 ± 0.0c	1.9 ± 0.1c	2.1 ± 0.1d	1.9 ± 0.1d	2.8 ± 0.1e	3.2 ± 0.1e	3.3 ± 0.1e	3.1 ± 0.2d	2.5 ± 0.1c	3.0 ± 0.1d	3.1 ± 0.1e	2.9 ± 0.2d	1.8 ± 0.1c	2.1 ± 0.1c	2.4 ± 0.1d	2.1 ± 0.2d
T_4	0.6 ± 0.0b	0.6 ± 0.0b	0.7 ± \0.0b	0.6 ± 0.0b	1.9 ± 0.0b	2.3 ± 0.0a	2.4 ± 0.1b	2.2 ± 0.2b	3.4 ± 0.1b	4.0 ± 0.1b	4.2 ± 0.1b	3.8 ± 0.2b	2.9 ± 0.1b	3.5 ± 0.1b	3.8 ± 0.1b	3.4 ± 0.3b	2.1 ± 0.0ab	2.5 ± 0.1a	2.8 ± 0.1b	2.4 ± 0.2b
T_5	0.5 ± 0.0c	0.5 ± 0.0c	0.6 ± 0.0c	0.5 ± 0.0c	1.9 ± 0.0b	2.1 ± 0.1b	2.2 ± 0.1c	2.1 ± 0.1c	3.2 ± 0.1c	3.6 ± 0.1c	3.8 ± 0.1c	3.5 ± 0.2c	2.9 ± 0.1b	3.2 ± 0.1c	3.4 ± 0.1c	3.2 ± 0.2c	2.0 ± 0.0b	2.2 ± 0.1b	2.5 ± 0.1c	2.2 ± 0.1c
T_6	0.3 ± 0.0g	0.3 ± 0.0g	0.4 ± 0.0g	0.3 ± 0.0g	1.5 ± 0.0d	1.7 ± 0.1de	1.7 ± 0.1g	1.6 ± 0.1e	2.4 ± 0.0g	2.8 ± 0.1g	2.9 ± 0.1g	2.7 ± 0.2ef	2.2 ± 0.0d	2. 6 ± 0.1f	2.7 ± 0.1g	2.5 ± 0.2f	1.6 ± 0.0de	1.8 ± 0.1d	2.1 ± 0.1g	1.8 ± 0.1e
T_7	0.5 ± 0.0d	0.5 ± 0.0d	0.5 ± 0.0d	0.5 ± 0.0d	1.7 ± 0.0c	1.9 ± 0.1c	2.0 ± 0.1e	1.9 ± 0.1d	3.1 ± 0.1g	3.4 ± 0.1d	3.6 ± 0.1d	3.3 ± 0.2c	2.6 ± 0.1c	3.0 ± 0.1d	3.2 ± 0.1d	3.0 ± 0.2d	1.8 ± 0.0c	2.1 ± 0.1c	2.3 ± 0.1e	2.1 ± 0.1d
T_8	0.6 ± 0.0a	0.7 ± 0.0a	0.7 ± 0.0a	0.7 ± 0.0a	2.2 ± 0.1a	2.3 ± 0.1a	2.6 ± 0.1a	2.4 ± 0.1a	3.7 ± 0.1g	4.1 ± 0.1a	4.3 ± 0.1a	4.1 ± 0.2a	3.1 ± 0.1a	3.7 ± 0.1a	4.0 ± 0.1a	3.6 ± 0.3a	2.2 ± 0.1a	2.6 ± 0.1a	2.9 ± 0.1a	2.5 ± 0.2a
LS	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	3.7	4.1	2.4	4.1	6.4	6.4	2.4	4.3	2.2	1.6	1.4	7.0	6.3	5.8	1.6	4.1	6.6	6.4	2.1	4.3

Each value represents the average of three replicates. In column, the mean values superscripted with similar letter(s) are statistically identical as per Duncan's Multiple Range Test. T = Treatment, T_0 = control, T_1 = rice straw + vermicompost + green manuring, T_2 = cow dung + vermicompost + green manuring, T_3 = compost + vermicompost + green manuring, T_4 = poultry manure + vermicompost + green manuring, T_5 = *T. harzianum* + vermicompost + green manuring, T_6 = mung bean straw + vermicompost + green manuring, T_7 = *T. viride* + vermicompost + green manuring, T_8 = chemical fertilizer, LS = Level of significance, **= 1% level of significance, CV = Coefficient of variation.

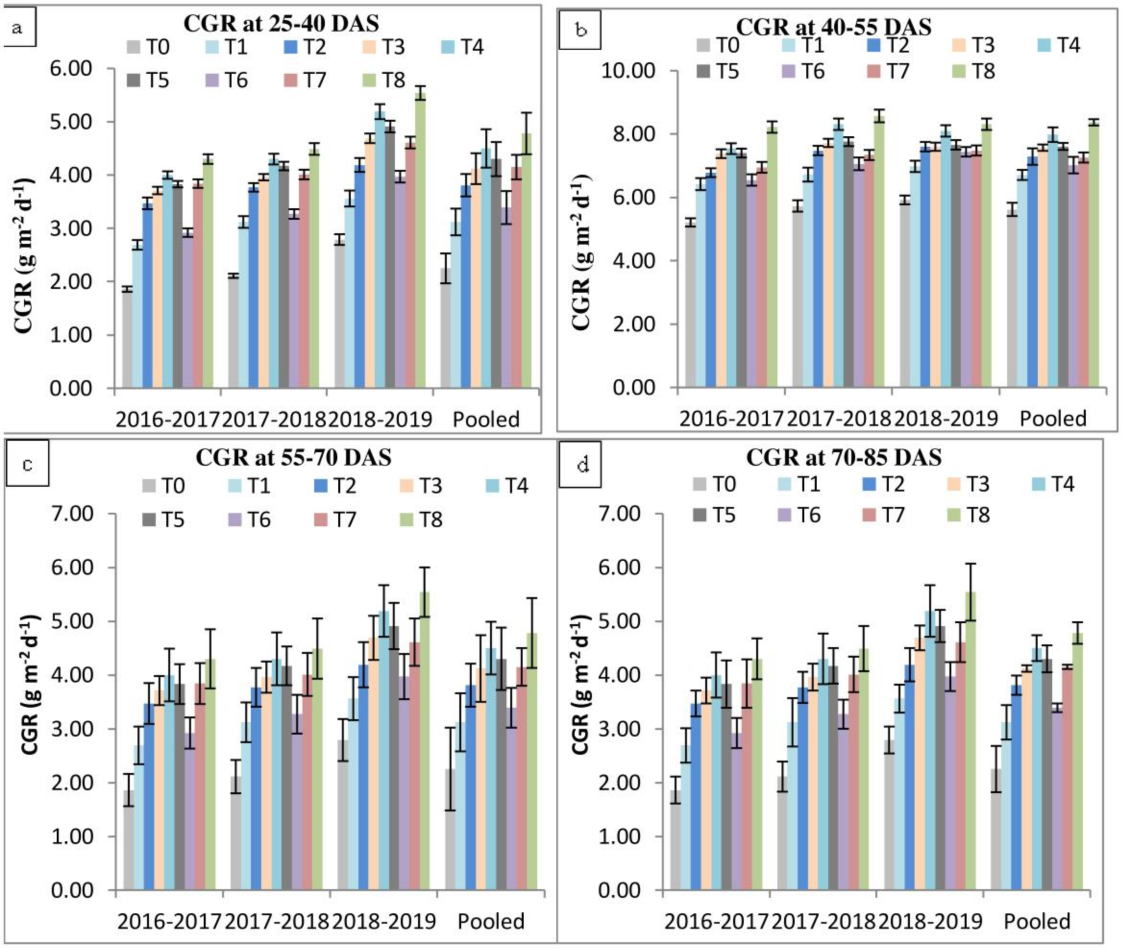

Fig. 1: Effect of probiotic and organic fertilizers as soil amendment on crop growth rate at a) 25-40, b) 40-55, c) 55-70 and d) 70-85 days after sowing of wheat [T_0 = control, T_1 = rice straw + vermicompost + green manuring, T_2 = cow dung + vermicompost + green manuring, T_3 = compost + vermicompost + green manuring, T_4 = poultry manure + vermicompost + green manuring, T_5 = *T. harzianum* + vermicompost + green manuring, T_6 = mung bean straw + vermicompost + green manuring, T_7 = *T. viride* + vermicompost + green manuring, T_8 = chemical fertilizer].

production of more leaves resulting in increased leaf area (Sims and Wolf, 1992). Ogundare *et al.* (2012) and Kareem *et al*. (2017) confirmed the judgments through their research outcome.

Crop growth rate (CGR)

The data indicated that the soil amendments had significant effect on wheat CGR for all sampling dates. However, with few exceptions pooled data revealed that the chemical fertilizer had the highest activity in the enhancement of CGR than poultry manure + vermicompost + green manure where the lowest value was recorded in untreated control (Fig. 1). The maximum CGR rate (20.3 g m^{-2} d^{-1}) was found in chemical fertilizer treatment while 2^nd^ highest value (19.1 g m^{-2} d^{-1}) was recorded from poultry manure-based combination. The minimum CGR value (15.1 g m^{-2} d^{-1}) was recorded in untreated control at 55-70 DAS. In case of 70-85 DAS, poultry manure + vermicompost + green manure showed the higher value (16.7 g m^{-2} d^{-1}) for CGR than chemical fertilizer treatment (15.8 g m^{-2} d^{-1}). The crop growth rate was demonstrated slow increase at the initial stage of wheat and later reached the peak at 55-70 DAS, and then declined in late growth stage. This observation may be linked to the delayed nutrient availability from poultry manure at early plant growth stage that produced less dry matter and then produced more dry matter in slow-fast-slow growth trend (Geng *et al.*, 2019). However, afterwards the decrease in CGR was noticed due to leaf senescence and tiller drying. These results are is an agreement with those of Boateng *et al.* (2006) and Ram (2017).

Conclusion: Chemical fertilizer gave effective results but its long-term use is not good for crop and soil health, therefore, organic soil amendment needs to be emphasized. Under this study potential and sustainable improvement of wheat growth with organic soil amendment was found. Inclusion of green manure, vermicompost and poultry manure may be a suitable alternative of chemical fertilizer for wheat growth. The capacity of surprising decomposition and nutrient release from those organic manures could be used to synchronize the nutrient demand of wheat. Data revealed that organic manures particularly poultry manure is a healthier source for improvement wheat growth as compared to other manures.

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SUSTAINABILITY OF WHEAT (*Triticum aestivum* L.) YIELD AND IMPROVEMENT OF SEED QUALITY THROUGH PROBIOTIC AND ORGANIC SOIL AMENDMENT

M.A. Hossain[1, 2], S.M.S. Islam[1] and M.M. Hasan[3]

[1]Plant Biotech.& Genetic Eng. Lab., Inst. of Biol. Sci., University of Rajshahi
[2]Directorate of Secondary and Higher Education, Dhaka-1000
[3]Plant Path. Lab., Agron. & Agril. Extn. Dept., University of Rajshahi
Corresponding E-mail:mahmudul742001@yahoo.com

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Abstract

In search of alternative counter to harmful effects of chemical fertilizers on soils and environment, probiotic and organic manures-based fertilizer management options need to be evaluated. The experiments were designed as randomized complete block design (RCBD) consisting of three wheat varieties and nine soil amendment treatments. The result revealed that organic amendments had prominent and variable effects on studied parameters and statistically at par with chemical fertilizer. Some yield-associated parameters like spike length, spikeletsspike^{-1}, fertile spikelets spike^{-1}, grains spike^{-1}, grains weight spike^{-1} and 1000-grain weight were significantly influenced by organic amendments. Moreover, grain yield and straw yield were increased73% and 27%, respectively under the treatment of poultry manure combination in comparison with control. In addition, the seed quality characters viz. germination, vigor index and total soluble protein content also exhibited significant improvement showing23%, 44%and 17%, respectively by poultry manure + vermicompost + green manure. The above findings showed that to apply poultry manure + vermicompost + green manure as an effective soil amendment option and to obtain good yield and quality seed of wheat.

Introduction

In Bangladesh, wheat occupies 4% of the total cropped area and 11% of the cropped area in the *Rabi* season and contributes 7% to the total output of food cereals (BBS, 2008). In Bangladesh, the average yield of wheat is 3.16 t ha^{-1} (BBS, 2017), which is below the achievable yield of 4.5 t ha^{-1} (BARI, 2011). Alam *et al.* (2013) stated two reasons for the yield gap as (i) biotic factors including poor quality seeds and seedlings, insects, diseases, weeds and rodents; and (ii) abiotic factors including soil, nutrients and water. However, many reasons for this yield gap remain unexplained. Nutrients availability of soils is declining with time pace but which had been rich in the past. Among the different agricultural inputs, fertilizer is the most important one and nearly 50% of the modern agricultural production depends on this insert (Pradhan, 1992). The non-judicial and imbalanced use of chemical fertilizer generate hazards on soil, environment and human health which led the growers' considerable attention to turn organic manures application for sustainable production practices (Singh *et al.*, 2018). It is authentic that fairly good soil fertility and plant nutrients are important to farming, whether the practices are considered "conventional" or "sustainable" (Hue and Silva, 2000). Yadvinder-Singh *et al.* (2008) stated organic materials like crop residues, green manure, and animal manure show great influence on soil productivity. Therefore, probiotic and organic manures application should be evaluated on agricultural land reclamation and crop yield potentiality aspects in Bangladesh. In this view, the investigation was carried out to assess the effect of probiotic and organic manure amendment soil on the yield and seed quality of wheat.

Materials and Methods

The present piece of research work was conducted in the Institute of Biological Sciences (IBS) and Plant Pathology Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh during the period from July 2016 to June 2019. The experimental field is geographically situated at 24°17" N latitude and 88°28" E longitude at an elevation of 20 m above the sea level belonging to the Agro-ecological Zone-11(AEZ-11). The soil of the experimental field is characterized by poorly drained with moderate permeable, loamy and slightly alkaline (pH = 8.10) in nature. Before 2016, the field was occupied with barley production for two years. The experiment was laid out in randomized complete block design (RCBD) with three replications. Three wheat varieties viz. BARI Gom-28 (V_1), BARI Gom-29 (V_2), BARI Gom-30 (V_3)and nine soil amendment treatments viz. control (T_0), rice straw + vermicompost + green manure (T_1), cow dung + vermicompost + green manure (T_2), compost + vermicompost + green manure (T_3), poultry manure + vermicompost + green manure (T_4), *Trichoderma harzianum* + vermicompost + green manure (T_5), mungbean residue + vermicompost + green manure (T_6), *Trichoderma viride* + vermicompost + green manure (T_7) and chemical fertilizer (T_8) were used . The unit plot was 5.0 m^2 having the plot to plot 0.5 m, bed to bed 0.25 cm distances and 1m from surrounding the boundary. Seeds of *Dhaincha* (*Sesbania rostrata*) were sown at the rate of 50 kg $ha^{-1}$to the respective plots and after 50 days of sowing young succulent green plants were incorporated into the soil. Crop residues (rice straw, mungbean residue), cow dung, compost and poultry litter were applied @ 10 t ha^{-1} before 7 days of sowing. Vermicompost was applied @ 5 t $ha^{-1}$and *Trichoderma* spp. suspension (1 10^6 cfu g^{-1} @ 5 kg ha^{-1}) before sowing. In the case of chemical treatment, one-third of urea (200 kg ha^{-1}), TSP 160 kg ha^{-1}, MoP 45 kg ha^{-1} and Gypsum 115 kg ha^{-1} were used as basal dose (BARI, 2014). The rest of the urea was applied as two installments one at 21 DAS and another at 55 DAS.

Data recording

In the case of yield and yield attributes, ten spikes were selected randomly from each experimental plot for recording data on spike length, spikeletsspike^{-1}, fertile spikelets spike^{-1}, grains spike^{-1} and grain weight spike^{-1}, while 1000-grain weight, grain yield and straw yield of crops were recorded which were collected from one square meter area at the center of each unit plot.

Harvest index (%)

The harvest index denotes the ratio of grain yield (economic yield) to biological yield and was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Here, Biological yield= Grain yield + straw yield.

Determination of seed germination

Four hundred seeds of each treatment were taken for germination test as recommended by ISTA (1985). Germination of seeds was collected regularly for up to 10 days. Percentage of germination was determined as follows:

$$\text{Germination (\%)} = \frac{\text{No. of germinated seedling}}{\text{No. of seed set for germination}} \times 100$$

Vigor index

After setting seeds, the germination percentage was calculated from the final count. Vigor index was found out by using the following formula (Maguire, 1962):

$$\text{Vigor index} = \frac{\text{No. of normal seedlings (First count)}}{\text{Days to first count}} + - - - - - - - - - +$$

$$\frac{\text{No. of normal seedlings (Final count)}}{\text{Days to final count}}$$

The total soluble protein content of seed

A technique formerly defined by Guy *et al.* (1992) was performed with some modification to estimate the total soluble protein of seed using a spectrophotometer.

Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. The trial data for all parameters were analyzed statistically for analysis of variance (ANOVA) throughr-studio (http://www.rstudio.com/) of "Agricolae" package (https://CRAN.R project.org/package=agricolae) and Duncan's multiple range test (DMRT) was performed for comparing treatment means(Gomez and Gomez, 1984).

Results and Discussion

Effect of soil amendment on yield and yield attributes

Spike length

The spike length was affected significantly by various soil amendment treatments (Table 1). In the final year, it has been found that the treatment T_8(chemical fertilizer) produced the maximum spike length (8.60 cm) which was followed byT_4(poultry manure + vermicompost + green manure) (8.43 cm) while the smallest spike length recorded from T_0 (7.00 cm).It might be due to higher nutrient concentration and moisture retention of the soil amended with poultry manure combination treatment that led to the formation of longer spike length. This result was correlated with Ahmed *et al.* (2002). Nevertheless, green manure fortified poultry manure keeps the N balance which may enhanced the length of spike of wheat. The above statement was also supported by Nguyen *et al.* (1995).

Spikelets spike^{-1} and fertile spikelets spike^{-1}

The spikelets spike^{-1} is treated as an important element of wheat grain yield (Sabaghina *et al.*, 2014). From Table 1, it revealed that spikelets spike^{-1} varied significantly from 13.80 to 17.97 where the maximum and the minimum value for this parameter were recorded from T_8 and T_0.

Nitrogen-rich organic manures may have a positive effect on the growth and yield attributes of wheat where higher fertile spikelet spike^{-1} from T_8 (17.24) and T_4 (17.00) but 13.22 was the lowest obtained from T_0. These findings were partially correlated with the observation of Siavoshi *et al.* (2011).

Grains spike^{-1}

Grains spike^{-1}is significantly influenced by soil amendments. During the research period, a significantly higher number of grains spike^{-1} was recorded from the treated plot in comparison with the control plot. The rank of treatments were T8>T_4> T_5> T_7> T_3> T_6> T_2> T_1> T_0 (Table 2). The maximum number of grains spike^{-1} (45.73) was recorded from T_8 which was statistically similar to T_4 (44.80) and the least value from T_0 (33.67). Considering the organic soil amendment treatments, poultry manure (T_4) performed the better response; such result might be due greater amount of N within it, which produced more dry matter and partitioning it towards grains which enhanced the grains spike^{-1}. This result was confirmatory with the outcomes of Shah *et al.* (2010) and Mukhtiar *et al.* (2018).

Table 1. Effect of organic and probiotic soil amendments on yield and yield contributing characters of wheat

Treatments	Spike length (cm)			Spikeletsspike^{-1} (no.)			Fertile spikeletsspike^{-1} (no.)		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
T_0	7.31e ± 0.16	7.12f ± 0.10	7.00e ± 0.05	14.66d ± 0.21	14.20d ± 0.20	13.80d ± 0.15	14.00g ± 0.20	13.78f ± 0.17	13.22f ± 0.19
T_1	7.45de ± 0.11	7.55e ± 0.11	7.63d ± 0.08	15.33c ± 0.14	15.50c ± 0.26	15.77c ± 0.17	14.74f ± 0.22	14.86e ± 0.13	15.08e ± 0.22
T_2	7.62cde ±0.12	7.73de ± 0.11	7.84d ± 0.08	15.60c ± 0.12	15.86c ± 0.20	16.10c ± 0.14	15.20de ± 0.12	15.32d ± 0.10	15.51d ± 0.13
T_3	7.77bcd ±0.09	7.99bcd ± 0.12	8.18c ± 0.10	16.10b ± 0.14	16.40b ± 0.23	16.63b ± 0.16	15.50cd ± 0.14	15.72c ± 0.12	15.93c ± 0.08
T_4	8.12ab ± 0.12	8.29ab ± 0.11	8.43ab ± 0.08	17.16a ± 0.13	17.59a ± 0.17	17.81a ± 0.16	16.60a ± 0.16	16.78a ± 0.09	17.00a ± 0.13
T_5	7.91bc ± 0.10	8.12abc ± 0.07	8.25bc ± 0.06	16.43b ± 0.14	16.68b ± 0.16	16.88b ± 0.21	15.90b ± 0.16	16.16b ± 0.15	16.40b ± 0.17
T_6	7.54cde ± 0.10	7.66de ± 0.08	7.77d ± 0.08	15.51c ± 0.15	15.78c ± 0.20	16.01c ± 0.17	14.90ef ± 0.18	15.10de ± 0.17	15.41de ± 0.15
T_7	7.79bcd ± 0.12	7.95cd ± 0.09	8.08c ± 0.06	16.26b ± 0.19	16.46b ± 0.11	16.70b ± 0.19	15.62bc ± 0.15	15.89bc ± 0.13	16.12bc ± 0.16
T_8	8.27a ± 0.08	8.41a ± 0.09	8.60a ± 0.10	17.36a ± 0.17	17.68a ± 0.16	17.97a ± 0.17	16.89a ± 0.13	17.06a ± 0.10	17.24a ± 0.18
LS	**	**	**	**	**	**	**	**	**
CV (%)	4.58	4.03	2.93	2.76	3.23	3.23	2.42	2.00	2.61

In the column, mean values bearing similar letter(s) or without letter are similar and those having dissimilar letters are differed significantly as per Duncan's Multiple Range Test. T_0 = control, T_1= rice straw + vermicompost + green manure, T_2 = cow dung + vermicompost + green manure, T_3 = compost + vermicompost + green manure, T_4 = poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = mungbean residues + vermicompost + green manure, T_7 = *T. viride*+ vermicompost + green manure, T_8 = chemical fertilizer, LS = Level of significance, **= 1% level of significance, CV = Coefficient of variation

Grains weight spike^{-1}

As a yield component, grains weight spike^{-1} of wheat is an important factor that contributes to the grain yield (Peltonen-Sainio *et al.*, 2007). Grain weight spike^{-1} at harvest varied significantly due to different soil amendment treatments (Table 2). Among the different soil amendment treatments, T_4 (2.14 g) performed better than other treatments. The rest of the treatments were also showed as descending by T_5 (2.06 g), T_7 (2.01 g), T_3 (1.99 g), T_2 (1.93 g), T_6 (1.89 g), T_1 (1.86 g), while the lowest one in T_0 (1.60 g). The advancement of grain weight spike^{-1} that provided with poultry manure treatment combination might be due to balanced nutrient stock during the grain filling stage and improvement of soil fertility. A similar result was also reported by Garg and Bahla (2008).

1000-grain weight

For cereal crops, 1000-grain weight is an important factor to determine the yield and yield attributes (Metho *et al.*, 1998). The data of 1000-grain weight of wheat indicated that chemical fertilizer (T_8) and poultry manure combination (T_4) significantly increased the weight (54.12 g and 53.90 g) while plants that did not receive any soil amendments (T_0) showed the lowest (48.78 g) might be due to availability of nutrients throughout the growing period and improvement of soil characters. This outcome was agreed with Ahmed *et al.* (2017).

Table 2. Effect of organic and probiotic soil amendments on yield and yield contributing characters of wheat

Treatments	Grains spike^{-1}(no.)			Grain weight spike^{-1}(g)			1000-grainweight (g)		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
T_0	36.88f ± 0.30	35.04e ± 0.30	33.67i ± 0.87	1.66g ± 0.03	1.62g ± 0.02	1.60g ±0.04	49.52f ± 0.44	48.61e ± 0.51	48.78i ± 0.41
T_1	36.98f ± 0.22	38.42d ± 0.23	39.53h ± 0.88	1.74f ± 0.02	1.80f ± 0.03	1.86f ± 0.04	50.03f ± 0.37	51.05d ± 0.30	51.30h ± 0.31
T_2	38.11e ± 0.21	39.36d ± 0.26	40.67f ± 0.96	1.80ef ± 0.03	1.88de ± 0.03	1.93e ± 0.05	51.19de ± 0.33	51.84bcd ± 0.59	51.95f ± 0.33
T_3	38.76d ± 0.21	40.51c ± 0.39	41.58e ± 1.02	1.83de ± 0.02	1.91d ± 0.03	1.99d ± 0.04	51.77cd ± 0.19	52.34a-d ±0.34	52.49e ± 0.34
T_4	42.11b ± 0.40	43.50a ± 0.59	44.80b ± 1.13	1.98b ± 0.02	2.10b ± 0.02	2.14b ± 0.05	52.94ab ± 0.27	53.51ab ± 0.47	53.90b ± 0.39
T_5	40.17c ± 0.22	41.59b ± 0.43	43.14c ± 1.08	1.93bc ± 0.03	2.02c ± 0.02	2.06c ± 0.05	52.27bc ± 0.21	52.98abc ± 0.90	53.19c ± 0.38
T_6	37.20f ± 0.20	38.71d ± 0.27	40.23g ± 0.97	1.77ef ± 0.03	1.84ef ± 0.03	1.89f ± 0.05	50.48ef ± 0.40	51.39cd ± 0.31	51.60g ± 0.34
T_7	39.73c ± 0.25	40.83bc ± 0.42	42.50d ± 1.07	1.89cd ± 0.02	1.99c ± 0.02	2.01d ± 0.05	51.97bcd ± 0.14	52.51a-d ± 0.26	52.64d ± 0.36
T_8	42.74a ± 0.37	44.41a ± 0.53	45.73a ± 1.04	2.07a ± 0.03	2.15a ± 0.03	2.20a ± 0.05	53.28a ± 0.30	53.81a ± 0.29	54.12a ± 0.40
LS	**	**	**	**	**	**	**	**	**
CV (%)	1.52	2.55	1.09	3.69	2.90	1.48	1.90	3.12	1.23

In the column, mean values bearing similar letter(s) or without letter are similar and those having dissimilar letters are differed significantly as per Duncan's Multiple Range Test. T_0 = control, T_1= rice straw + vermicompost + green manure, T_2 = cow dung + vermicompost + green manure, T_3 = compost + vermicompost + green manure, T_4 = poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = mungbean residues + vermicompost + green manure, T_7 = *T. viride*+ vermicompost + green manure, T_8 = chemical fertilizer, LS = Level of significance, **= 1% level of significance, CV = Coefficient of variation

Grain yield

Different yield component specifically spikesm^{-2}, number and weight of grains spike^{-1} and 1000-grain weight mathematically functioned on yield of cereal crop (Thiry *et al.*, 2002). Application of different soil amendments showed significant variation of grain yield of wheat (Figure 1, 2 and 3). In the last year, influences of different treatments on grain yield were found to be ranked in that following descending order T_8 (4.25 t ha^{-1}) > T_4 (4.09 t ha^{-1}) > T5 (3.85 t ha^{-1}) > T_7 (3.64 t ha^{-1}) > T_3 (3.60 t ha^{-1}) > T_2 (3.34 t ha^{-1}) > T_6 (3.27 t ha^{-1}) > T_1 (3.05 t ha^{-1}) > T_0 (2.36 t ha^{-1}). Better performance of T_4 might be enhanced soil fertility and improvement of physical conditions, reduction of nutrient losses which collectively contributed to the higher grain yield. This result was in confirmed to that with the observation of Zhang *et al.* (2016).

Straw yield

Soil amendments significantly influenced the straw yield (Figure 1, 2 and 3). Among the different treatments, T_8 (5.40 t ha^{-1}) performed superior. The rest of the treatments were also showed significant result ranked as descending by T_4 (5.31 t ha^{-1}), T_5 (5.14 t ha^{-1}), T_7 (5.05 t ha^{-1}), T_3 (4.93 t ha^{-1}), T_6 (4.83 t ha^{-1}), T_2 (4.73 t ha^{-1}) and T_1 (4.60 t ha^{-1}), while the lowest one in T_0 (4.18 t ha^{-1}). This performance of organic manures might be due to the capability of abundant nutrients supply and the creation of a favorable growth environment. A similar result was also noted by Auti *et al.* (1999) and Kumar and Abraham (2018).

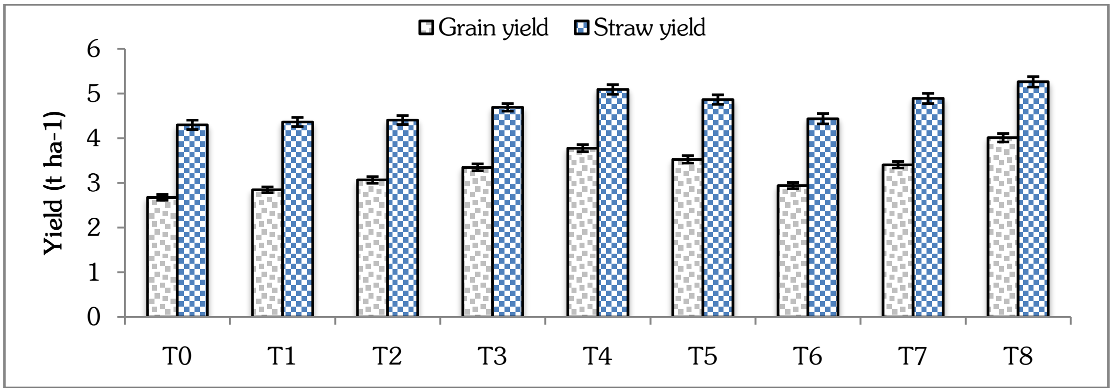

Fig. 1. Effect of organic and probiotic soil amendments on grain yield and straw yield of wheat in 2016-2017.

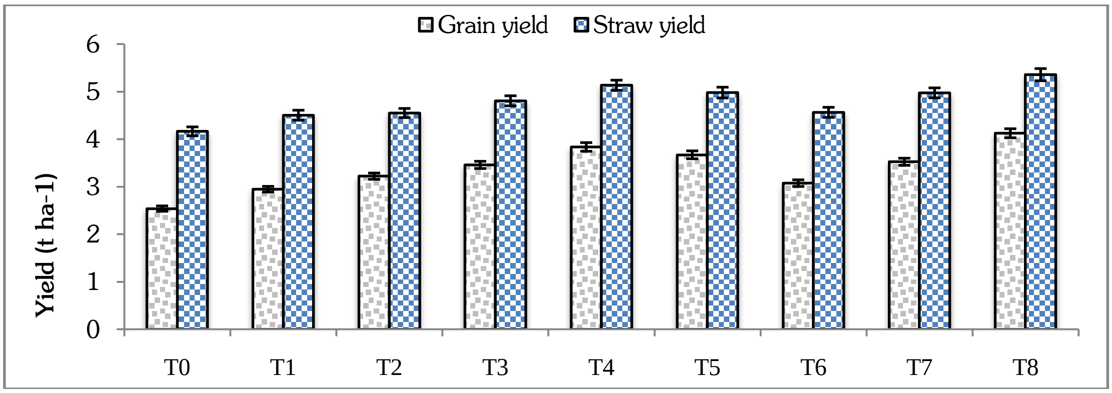

Fig. 2. Effect of organic and probiotic soil amendments on grain yield and straw yield of wheat in 2017-2018.

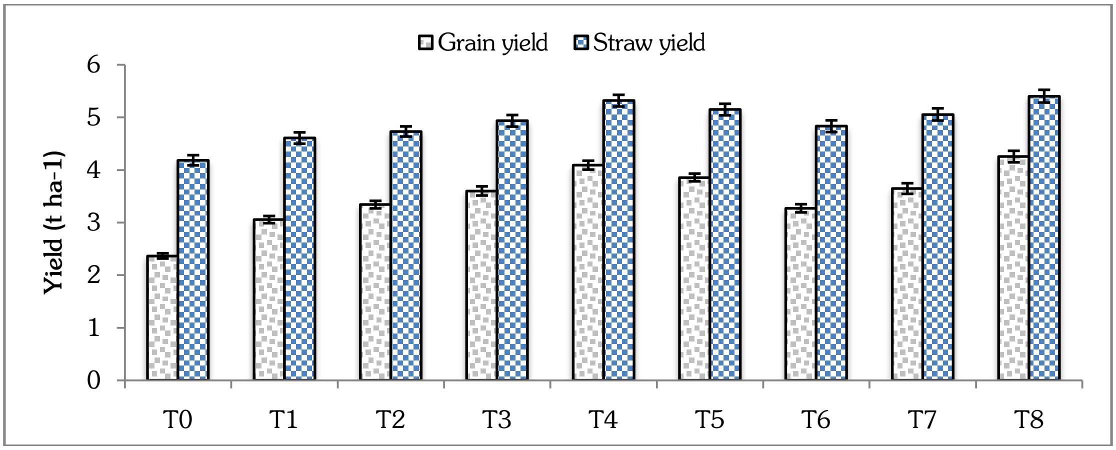

Fig. 3. Effect of organic and probiotic soil amendments on grain yield and straw yield of wheat in 2018-2019.

Harvest index

Treatment T_8 showed a maximum harvest index (44.05%) followed by T_4 (43.48%) and the lowest one (36.13%) derived from T_0 during 2018-2019 (Figure 4).The boosting harvest index might be the continued supply of nutrients and higher dry matter distribution towards grain formation provided by the poultry manure treatment combination. This result was in agreement with the investigation of Kabesh *et al.* (2009) and Khan *et al.* (2018).

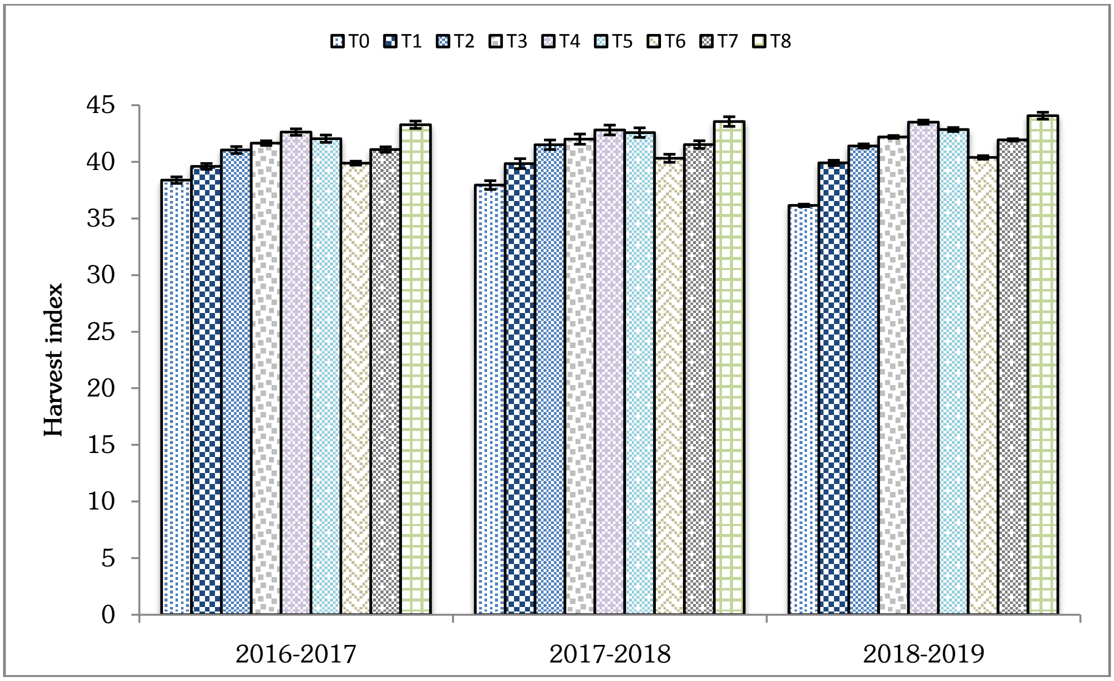

Fig. 4. Effect of organic and probiotic soil amendments on harvest index of wheat in 2016-2017, 2017-2018 and 2018-2019.

Effect of soil amendments on seed quality

After every harvesting, seeds were collected separately from each treatment and preserved. Major seed quality characters viz. germination, vigor index and total soluble protein content were determined. The introduction of designed soil amendments not only developed the growth and yield of wheat but also enriched parameters of seed quality.

Germination (%)

Soil amendments influenced the germination of seed. The treatment T_4 significantly enhanced (92.08%) the germination followed by T_5 (88.89%) and T_0 had a lower effect (74.78%) on germination in 2018-2019 (Table 3). A similar trend was also observed in the previous two cropping season. This might be due to an adequate supply of nutrients which helps to build up carbohydrate-like seed elements thus producing vigorous seeds. The outcome of the investigation was the conformity of previous results of Gowda *et al.* (2010) and Aslam *et al.* (2011).

Table 3. Effect of organic and probiotic soil amendments on seed quality of wheat

Treatments	Germination (%)			Vigor index			Soluble protein content(mg g^{-1} FW)		
	2016-2017	**2017-2018**	**2018-2019**	**2016-2017**	**2017-2018**	**2018-2019**	**2016-2017**	**2017-2018**	**2018-2019**
T_0	70.50h ± 0.92	72.53g ± 0.93	74.78g ± 0.85	24.70h ± 0.42	27.49f ± 0.40	28.84f ± 0.27	77.31e ± 0.28	77.47e ± 0.58	79.10e ± 0.42
T_1	75.31g ± 1.08	77.54f ± 1.02	79.67f ± 1.18	28.20g ± 0.55	32.52e ± 0.54	34.39e ± 0.36	78.20e ± 0.45	79.68d ± 1.05	79.58e ± 0.52
T_2	78.14f ± 0.82	80.88de ± 0.98	83.67d ± 0.96	31.69e ± 0.85	34.42d ± 0.96	35.93d ± 0.38	80.25d ± 0.46	80.97cd ± 0.73	82.98d ± 0.39
T_3	81.08d ± 0.85	83.86bc ± 0.92	86.17c ± 0.94	32.60d ± 0.43	36.84b ± 0.49	38.36b ± 0.34	80.20d ± 1.02	81.98c ± 1.44	82.24d ± 1.28
T_4	88.27a ± 1.05	89.93a ± 1.01	92.08a ± 1.24	35.99a ± 0.73	39.48a ± 0.84	41.54a ± 0.58	88.17b ± 1.89	93.30a ± 0.90	92.56b ± 0.70
T_5	84.75b ± 1.06	86.52b ± 1.15	88.89b ± 0.84	34.57b ± 0.52	37.30b ± 0.58	39.26b ± 0.46	87.59b ± 0.59	88.30b ± 0.66	91.03c ± 0.99
T_6	78.76e ± 0.89	78.40ef ± 1.46	81.83e ± 1.42	30.21f ± 0.46	34.68d ± 0.33	35.37de ± 0.33	81.51c ± 0.72	81.31c ± 0.63	82.62d ± 0.70
T_7	83.59c ± 0.93	83.33cd ± 1.05	86.28c ± 0.96	33.56c ± 0.43	35.78c ± 0.38	36.98c ± 0.42	87.88b ± 0.58	89.17b ± 0.83	91.99bc ± 0.67
T_8	81.37d ± 0.86	84.57bc ± 1.05	86.76c ± 01.16	32.46d ± 0.50	34.03d ± 0.34	37.27c ± 0.48	93.32a ± 1.08	93.80a ± 1.20	96.43a ± 1.14
LS	**	**	**	**	**	**	**	**	**
CV (%)	0.82	3.34	1.79	0.97	3.16	2.91	1.58	1.61	1.42

In the column, mean values bearing similar letter(s) or without letter are similar and those having dissimilar letters are differed significantly as per Duncan's Multiple Range Test. T_0 = control, T_1= rice straw + vermicompost + green manure, T_2 = cow dung + vermicompost + green manure, T_3 = compost + vermicompost + green manure, T_4 = poultry manure + vermicompost + green manure, T_5 = *T. harzianum* + vermicompost + green manure, T_6 = mungbean residues + vermicompost + green manure, T_7 = *T. viride*+ vermicompost + green manure, T_8 = chemical fertilizer, LS = Level of significance, **= 1% level of significance, CV = Coefficient of variation

Vigor index

The vigor index is an imperative quality of seed that indicates the potentiality of constant emergence of seedlings (Pradeep, 2018). After three years of experimentation, considering the comparable trend of vigor index from respective treatments, poultry manure (41.54) and *Trichoderma harzianum* (39.26) in comparison with control treatment (28.84).The speed of germination i.e. vigor index might be significantly different for providing the substantial macro and micro nutrient in the grain filling stage and carbohydrate stored in seed enhances the quality. This result was in agreement with the reflection of Farhad *et al.* (2011).

Total soluble protein content

Among the major cereals, wheat is the prominent source of vegetal protein (13%). The results in general T_8 produced higher protein (96.43 mg g^{-1} FW) followed by T_4 (92.56 mg g^{-1} FW) and the least at T_0 (79.10 mg g^{-1} FW). The increase of protein content might be due to the availability of high NPK that satisfy the plant requirement and accumulated N in leaf mobilized to seed components which leads the protein production. This result was in corroborates with the findings of Abedi *et al.* (2010) and Rasul *et al.* (2015). Considering the fact, the poultry manure combination treatment (T_4) was an environmentally friendly alternative to chemical fertilizer (T_8) for increasing soil fertility and crop productivity.

Conclusion

There is a potentiality for sustainable improvement of wheat growth, yield and seed quality with organic soil amendment through probiotic and organic manure. In that term, the inclusion of green manure, vermicompost and poultry manure might be a worthy alternative. Organic manures particularly poultry manure was a healthier source for improvement of growth, yield parameters and seed quality of wheat as compared to other manures. So, the poultry manures could be suggested for soil amendment and increase wheat production in the studied region.

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EFFECTS OF PROBIOTIC AND ORGANIC MANURES FOR SOIL AMENDMENTS ON SEEDLING SURVIVABILITY AND LEAF CHLOROPHYLL FOR CROP IMPROVEMENT IN WHEAT (*TRITICUM AESTIVUM* L.)

MA Hossain[1,2], MM Hasan[3] and SMS Islam[1*]

[1]Plant Biotechnology and Genetic Engineering Laboratory, Institute of Biological Sciences, University of Rajshahi, Rajshahi-6205, Bangladesh
[2]Directorate of Secondary and Higher Education, Dhaka-1000, Bangladesh
[3]Agronomy and Agricultural Extension Department, University of Rajshahi, Rajshahi-6205, Bangladesh

Abstract

Under this study a total of nine treatments were considered for soil amendments where organic manures, chemical fertilizer and probiotics were used to evaluate the efficiency on growth and yield of wheat. On the basis of seedling disease incidence and chlorophyll presence parameters data were recorded on seedling infection at 14 days, seedling blight at 21 days, and chlorophyll content at 70 days after sowing. In this study the same experiments were conducted up to three years (2016-2019) and data were compiled and analyzed. It was observed that the disease prevalence attributes significantly decreased in T_5 (*Trichoderma harzianum* + vermicompost + green manuring) than other treatment combinations and control (T_0). Noteworthy results were found on seedling health, application of probiotic and organic manures which significantly influenced the less infection of wheat. Besides this, chlorophyll content of wheat leaf and plant number with effective tiller enhanced largely under T_8 (chemical fertilizer) than T_4 (poultry manure + vermicompost + green manuring) and control (T_0). The main advantage of this research is to evaluate efficiency for growing healthy wheat plant which reflects on plant growth and yield and ultimately helps for food security.

Key words: Blight, Chlorophyll, Green and poultry manure, Infection, Vermicompost, Wheat

Introduction

Wheat (*Triticum aestivum* L.) is a staple food of billions of people all over the world and third most agricultural commodity next to rice and maize. The contribution of wheat is being increased significantly in different countries as Nigeria (1% - 6.64%), India (11.85% - 20.41%) and China (12.20% - 17.83%) regarding total kcal (Shewry and Hey 2015). In Bangladesh, wheat is one of the important grain crops regarding economic and consumption purposes. Wheat is used as industrial and commercial products for human consumption having high protein with others nutrients that is also a cheaper source of feed for livestock (Hammad et al. 2011). Land engaged for cultivation decreased with time to meet up the accommodation demand for geometric growth of population. To face the land limitation problem and provide food for increased population, sustainable use of land is burning issue for agricultural development (Haque and Islam 2018, Alam et al. 2020). The substantial pressure on land may create various constraints due to imbalanced and inadequate

*Author for correspondence: shahinul68@gmail.com

application of fertilizer (Kumar and Abraham 2018). Chemical fertilizer may increase the wheat yield but prolonged application resulted human health hazard and imbalanced natural resources (Hossain et al. 2021a). So, need to link soil management and cropping design that are more environmentally sustainable (Karnel et al. 1994). Though transition period of three years produce lower performance but higher soil fertility found over time in conventional to organic farming (Tester 1990). So, for achieving higher yield and retain soil health sound organic amendments are felt to be important. A good soil should have organic matter content of more than 2.5%. Most of the soils in Bangladesh have low to very low organic matter content, generally less than 1.5% (BARC 2012). Soil productivity is greatly influenced by the application organic manures like crop residues, green manure and animal manure in the soil-plant system (Yadvinder-Singh et al. 2008, Hossain et al. 2021a). Probiotics are live microorganisms which confer a beneficial health benefit on the host. *Trichoderma* is considered as a probiotic having the characteristic of fungi and considered as a potential and promising bio-control agent and growth promoter for many crops. Bio-fertilizer is regarded as an eco-friendly substitute of chemical fertilizer trends to enhance soil fertility and increase crop productivity and yield without creating harm to the environment (Hermosa et al. 2012, Hossain et al. 2021b). It was established that *Trichoderma* is a biological degrader and promotes plant disease defense, increasing the immunity of the plant. Hence, *Trichoderma* have tremendous opportunities for disease management of soil borne pathogens but also have the capacity to improve plant growth parameters and soil health. It is authentic that fairly good soil fertility and plant nutrients are important to farming. Hence to improve soil fertility and increase plant nutrients availability, efforts need to be made to increase soil organic matter content. So, in view of the above realities an initiative was undertaken to focus the probiotic and organic manure performance on wheat seedling and plant growth resulted on yield, which may help to increase the productivity of wheat.

Materials and Methods

Soil and field preparation

The present research work has been carried out in the Experimental Field of the Institute of Biological Sciences (IBSc) and laboratory works has been carried out at Plant Biotechnology and Genetic Engineering Lab., IBSc and Plant Pathology Lab., Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh during the period from July 2016 to June 2019. The experimental field geographically situated at 24°17` N latitude and 88°28` E longitude at an elevation of 20 m above the sea level belonging to the Agro-Ecological Zone-11 (AEZ-11). The soil of the experimental field has characteristics like poorly drained with moderately permeability, loam and slightly alkaline (pH = 8.10) in nature. The physical properties of the experimental soil had moisture content 19.40%, particle density 2.65 g/cc, bulk density 1.27 g/cc and porosity 51.34%. Furthermore, chemical properties like the organic matter content 1.20%, K 0.150 cmol (+)/kg, total N 0.07%, P 26.30 µg/g, S 12.50 µg/g, Zn 0.75 µg/g, EC 145 µs/cm and C:N 10:1 were recorded.

Experimental design and treatments

The experiment was laid out in randomized complete block design (RCBD) with three replications. Three wheat varieties *viz*. BARI wheat-28 (V_1), BARI wheat-29 (V_2), BARI wheat-30 (V_3) and nine treatments (T) including control (T_0), rice straw + vermicompost + green manuring (T_1), cow dung + vermicompost + green manuring (T_2), compost + vermicompost + green manuring (T_3), poultry manure + vermicompost + green manuring (T_4), *Trichoderma harzianum* + vermicompost + green manuring (T_5), mung bean residue + vermicompost + green manuring (T_6), *Trichoderma viride* + vermicompost + green manuring (T_7) and chemical fertilizer (T_8) were used in this study. The unit plot was 5.0 m^2 having a plot to plot 0.5 m, bed to bed 0.25 cm distance and 1 m from surrounding the boundary. The total unit plot was 81. Seeds of *Dhaincha* (*Sesbania rostrata*) were sown at the rate of 50 kg/ha (BARI 2014) and after 50 days young succulent green manure plants incorporated into the soil to the respective plots (Dubey et al. 2015). Crop residues (rice straw and mung bean), cow dung, compost and poultry litter were applied at the rate 10 t/ha before 7 days of sowing. Vermicompost was applied 5 t/ha and *Trichoderma* spp. suspension (1×10^6 cfu/g at the rate 5 kg/ha) before sowing. In case of chemical treatment, one third urea (200 kg/ha), TSP 160 kg/ha, MP 45 kg/ha and gypsum 115 kg/ha was used as basal dose (BARI 2014). Rest of the urea was applied following two installments, one at 21 days after sowing (DAS) and rest one at 55 DAS.

Data collection on seedling health, leaf chlorophyll content and plant characters

Seedling infection

The seedlings which were found yellow and rotted at the base are considered as infected. From germination up to 14 days regular observation was made and infected seedlings were counted in each plot. Infection was estimated by the following formula:

$$\%\ \text{Seedling infection} = \frac{\text{Number of infected seedlings}}{\text{Total number of seedlings}} \times 100$$

Seedling blight

Seedlings which were dead and became straw in color defined as seedling blight. Seedling infection is treated as the first step of seedling blight. Thus, blighted seedlings were counted at 21 DAS in every plot. It was estimated as by the following formula:

$$\%\ \text{Seedling blight} = \frac{\text{Number of blighted seedlings}}{\text{Total number of seedlings}} \times 100$$

Leaf chlorophyll content

The atLEAF handled chlorophyll meter was used to assess leaf greenness. The meter determines light transmittance through the leaf at 660 and 940 nm wavelengths. The readings were obtained by inserting the middle portion of the topmost fully expanded leaf in the slit of the meter. At least three readings from leaves of randomly selected plants in each plot were recorded and mean value was determined. Abnormally looking or insect attacked plants were not selected for measurement (Ali et al. 2020).

Total plant/m^2

Before harvesting 1 m^2 area was selected with quadrate and the number of total plants was counted. This operation was done in each plot preferably choosing the five rows in the middle of the plot.

Effective tiller/plant

The numbers of tillers bearing panicles were counted at harvest with the help of quadrate from 1 m × 1 m area, which expressed as effective tillers/plant.

Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. The data were analyzed statistically for analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) through r-studio by the "Agricolae" package.

Results

Seedling infection

Regarding various treatments effect, the lower rate of seedling infection (0.32%) was found after application *Trichoderma harzianum* (T_5) in comparison with the maximum infection from T_0 (2.32%) in 2018-2019. All the treatments in the experimental period presented significant differences among each other. But T_1 (rice straw + vermicompost + green manuring) and T_8 (chemical fertilizer) was statistically identical. Reduction of seedling infection at 14 DAS under different soil amendments showed more or less the following order as $T_5>T_7>T_4>T_3>T_2>T_6>T_1>T_8>T_0$ during the whole research period shown in Table 1.

Seedling blight

Under this study, recorded results showed that there was a significant variation among the treatments. The highest inhibition effect against seedling blight (0.87%) was observed by treatment T_5 and the lowest (4.74%) from control (T_0) during 2018-2019 (Fig.1 a-b). Next to treatment T_5, the treatment T_7 also showed remarkable effect in reducing seedling blight (1.07%) which was statistically identical (1.09%) with T_4 (Table 1).

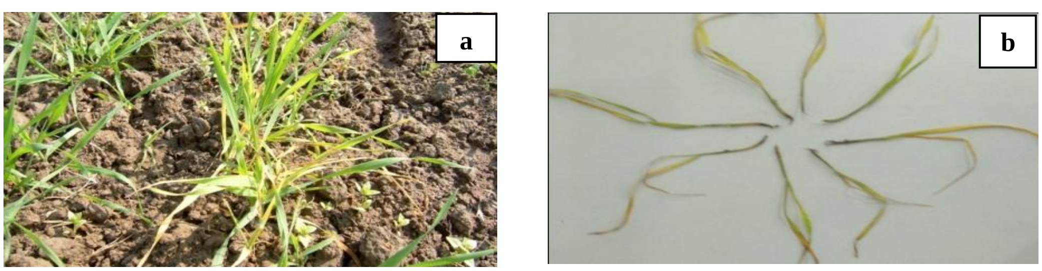

Fig. 1(a-b): Seedling status and plant growth by adding probiotic and organic manures for soil amendments, a) seedling infection and, b) seedling blight.

Leaf chlorophyll content

A significant difference was observed from various soil amendments for the chlorophyll content of wheat leaf at 70 DAS. The highest value of chlorophyll content (51.48 SPAD) was recorded from chemical fertilizer (T_8) and which was followed by T_4 (48.37 SPAD) and T_5 (48.08). In this regard, the smallest value (40.33 SPAD) was noticed from T_0 during the season 2018-2019. Due to soil amendment with chemical fertilizer (T_8)

provided more chlorophyll content and the trend was maintained from beginning to the end of the study (Table 1).

Table 1. Effect of organic and probiotic soil amendments on seedling infection and seedling blight of wheat

Treat.	Seedling infection (%)			Seedling blight (%)			Leaf chlorophyll content (SPAD)		
	14 DAS			21 DAS			70 DAS		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018 - 2019
T_0	2.14 ± 0.12a	1.99 ± 0.09a	2.32 ± 0.13a	3.52 ± 0.16a	3.30 ± 0.16a	4.74 ± 0.20a	38.26 ± 0.85h	38.82 ± 0.90g	40.33 ± 0.79d
T_1	1.49 ± 0.03b	1.47 ± 0.05b	1.46 ± 0.09b	2.53 ± 0.08b	2.41 ± 0.08b	2.48 ± 0.19c	40.18 ± 0.90g	41.62 ± 0.86f	42.77 ± 0.87c
T_2	1.34 ± 0.04d	1.24 ± 0.05c	1.20 ± 0.04c	2.17 ± 0.06c	2.04 ± 0.04d	2.11 ± 0.08d	41.39 ± 0.87f	43.56 ± 1.05de	42.96 ± 0.76c
T_3	0.93 ± 0.04e	0.87 ± 0.03d	0.92 ± 0.05d	1.77 ± 0.05d	1.71 ± 0.05e	1.61 ± 0.04e	42.45 ± 0.85d	43.85 ± 1.04d	44.09 ± 0.85c
T_4	0.59 ± 0.02f	0.58 ± 0.02e	0.55 ± 0.01e	1.24 ± 0.05e	1.19 ± 0.06f	1.09 ± 0.05f	44.59 ± 0.81b	46.63 ± 0.89b	48.37 ± 0.80b
T_5	0.35 ± 0.02g	0.34 ± 0.02g	0.32 ± 0.02g	0.93 ± 0.06f	0.87 ± 0.04g	0.87 ± 0.05g	43.03 ± 0.85c	44.73 ± 0.91c	48.08 ± 0.61b
T_6	1.43 ± 0.02c	1.44 ± 0.06b	1.42 ± 0.08b	2.44 ± 0.07b	2.33 ± 0.08bc	2.16 ± 0.11d	41.08 ± 0.89f	41.80 ± 0.92f	43.06 ± 0.63c
T_7	0.57 ± 0.02f	0.46 ± 0.02f	0.45 ± 0.03f	1.29 ± 0.04e	1.11 ± 0.03f	1.07 ± 0.06f	41.78 ± 0.92e	43.45 ± 0.95e	45.11 ± 0.71c
T_8	1.48 ± 0.10c	1.47 ± 0.08b	1.42 ± 0.04b	2.44 ± 0.09b	2.26 ± 0.04c	2.57 ± 0.11b	47.14 ± 0.97a	48.92 ± 1.08a	51.48 ± 0.70a
LS	**	**	**	**	**	**	**	**	**
CV (%)	5.42	6.89	4.38	5.59	6.16	4.30	0.80	0.79	5.09

Each value represents the average of three replicates. In the column, mean values bearing similar letter(s) or without letter are identical and those having dissimilar letters are differed significantly as per Duncan's Multiple Range Test. T_0 = control, T_1 = rice straw + vermicompost + green manuring, T_2 = cow dung + vermicompost + green manuring, T_3 = compost + vermicompost + green manuring, T_4 = poultry manure + vermicompost + green manuring, T_5 = *T. harzianum* + vermicompost + green manuring, T_6 = mung bean residues + vermicompost + green manuring, T_7 = *T. viride* + vermicompost + green manuring, T_8 = chemical fertilizer, SPAD = The soil plant analysis development. LS = level of significance, ** = 1% level of significance, CV = co-efficient of variation.

Total plant/m²

Total plant/m² at harvest varied significantly due to different soil amendments all over the study period. The highest frequency of total plant/m² was found in T_8 (199.11%) and the lowest result was recorded in T_0 (158.67%) in 2016-2017 (Fig. 2). The next highest value was recorded from T_4 (191.56%) and T_5 (185.00%) had the statistical likeness. In the year 2017-2018, total plant/m² exhibited the matching trend due to various soil amendments as reported in 2016-2017. Where the highest (207.78%) plant/m² produced by T_8 and had similar identity with the second most from T_4 (202.89%). The lowest total plant/m² (163.89%) was noticed in T_0 coupled with T_1 (170.22%). Among the different soil amendments T_8 (216.11%) performed superior results besides T_4 (209.89%) to other treatments in 2018-2019. Rest of the treatments were showed also significant difference ranked as descending by T_5 (199.78%), T_7 (190.22%), T_3 (187.22%), T_2 (179.00%), T_6 (177.67%) and T_1 (173.44%), whereas the lowest one in T_0 (159.00%).

Effective tiller/plant

Under this study, recorded results on effective tiller/plant showed significant difference by the influence of treatments. Out of different soil amendments, chemical fertilizer (T_8) and poultry manure (T_4) performed as superior to the rest of the treatments mainly unamend (T_0) all over the research period (Fig. 3). On the basis of the above statement, T_8 was produced the maximum number of effective tiller/plant (3.49%) followed by T_4 (3.40%), whereas the minimum value (2.07%) was given by T_0 in 2016-2017. During 2017-2018, treatments were exhibited approximately equal performance with slight increase of effective tiller/plant. However, 3.64% and 2.10% were the greater and less value of effective tiller/plant obtained by treatment T_8 and T_0. In the last year 2018-2019, the maximum value on this parameter was found from T_8 (3.89%) and T_4 (3.69%) and then gone downward as followed T_5 (3.36%) >T_7 (3.22) >T_3 (3.09) >T_2 (2.91%) >T_6 (2.84%) >T_1 (2.73%) over T_0 (2.16%).

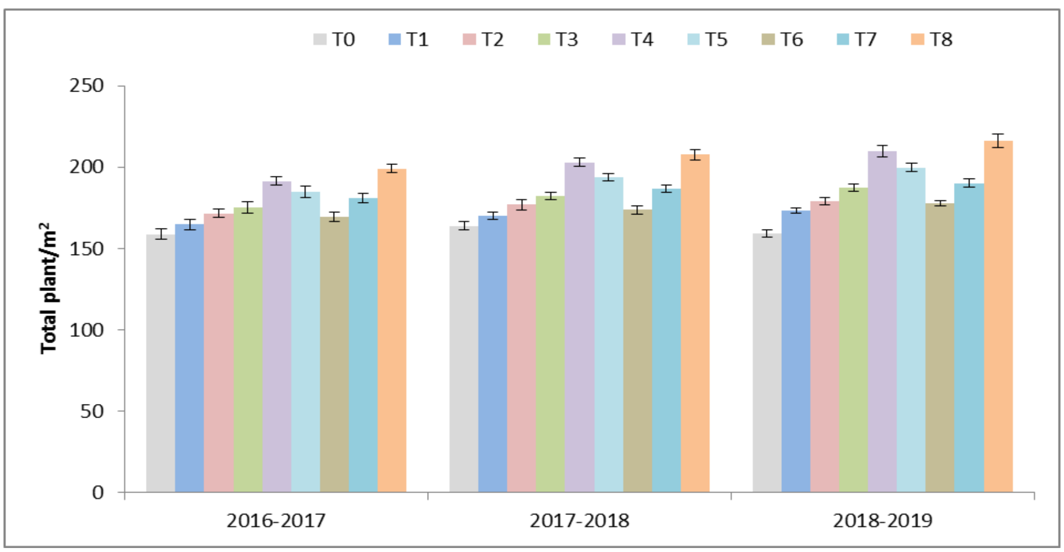

Fig. 2: Effect of organic and probiotic soil amendments on total plant/m² of wheat.

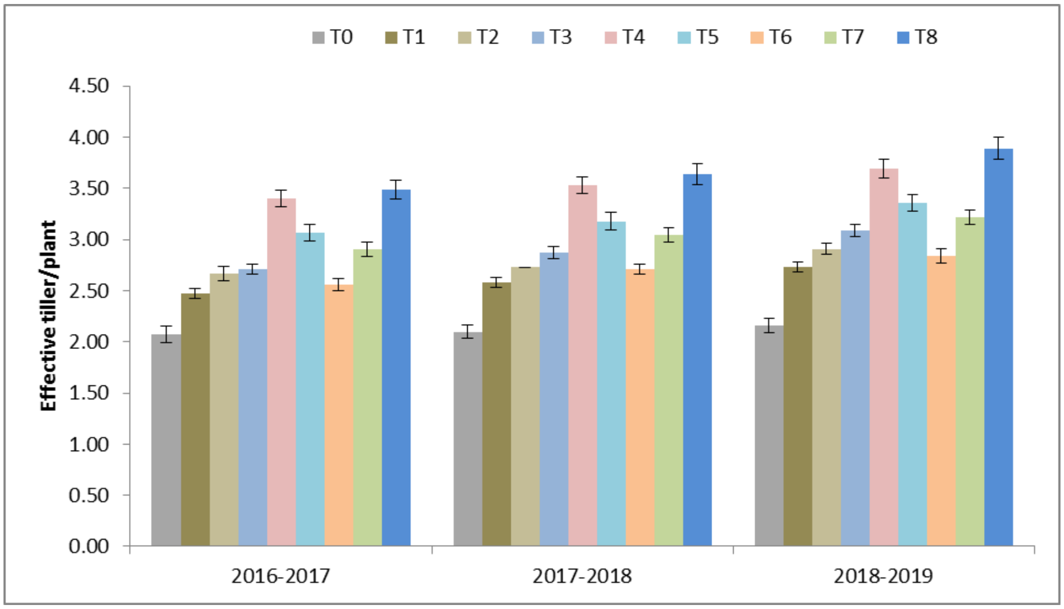

Fig. 3: Effect of organic and probiotic soil amendments on effective tiller/plant of wheat.

Discussion

Seedling infection

A significant variation of seedling infection was noticed all over the research period. The trend of infection was found to decline with the progress of the study due to application of probiotic and organic manure. The highest rate of seedling infection was found in T_0 (2.32%), while the minimum rate of infection was recorded from T_5 (0.32%) in 2018-2019. It might be due to the definite role of probiotic fortified-organic manures that exerted antagonistic effect against the fungi causing seedling infection. Furthermore, the addition of organic matter may create a hospitable environment for growth and development of fungal antagonists resulting in enhanced biocontrol activity (Sarkar et al. 2002). This finding was in harmony with the reports Tewari and Rajbir (2005).

Seedling blight

Seedling infection later on converted into seedling blight. Like seedling infection, this parameter was also varied significantly under various treatments all over the study period. The control activity against seedling blight was highly observed by T_5 (0.87%) and the lowest exhibited from check T_0 (4.74%) during 2018-2019. Such result may be obtained for the efficacy of the prohibitory and biocontrol action of the treatment. This efficacy of *Trichoderma* fortified-organic manures was evaluated to reduce the pre-emergence and post-emergence seedling mortality, diseases of stem and root of chickpea by Talukder et al. (2017). Similar control activity of *Trichoderma* spp. against plant pathogen and seedling mortality was also reported by Bhuiyan et al. (2007) and Ha 2010.

Leaf chlorophyll content

Chlorophyll content of leaf from diverse treatments was provided significant dissimilarities from beginning to end of the study. On the focus of organic amendments, treatment T_4 (48.37 SPAD) next to T_8 (51.48 SPAD) had the bigger accumulation of chlorophyll and the smaller was noticed from T_0 (40.33 SPAD). It may probably relate with the decomposition rate of organic manures that happened in case of T_4 treatment. This result was supported by Khan et al. (2005) with the statement that N supply in organic treatment is generally restricted and slows N mineralization as compared to crop demand of N. Chlorophyll content is closely related to the presence of N and poultry manure (T_4) had the higher ability of supplying N. This result is an agreement with the findings of Sims and Wolf (1992), Khanam et al. (2001), Ru et al. (2012) and Krishna (2013).

Total plant/m²

The parameter plant/m^2 is one of the major vegetative growth indicators of wheat. The best values of plant/m^2 were obtained from T_8 (216.11%) and then T_4 (202.81%) where the lowest at T_0 (158.66%). The ability of such enhancement plant/m^2 due to application of poultry manure might contain high amounts of nutrients and organic matter that improved the soil structure and environment which aids density of plant. Result in the study was in the same manner previously notified by Hassan (2002), Dauda et al. (2008) and Ismaeil et al. (2012).

Effective tiller/plant

Tillering is one of the important growth stages of wheat which provides the necessary stalks for satisfactory production. Though tillers are lateral branches which emerge from the main stem, but not all produce an ear. Generally, the first two-three tillers are noted as productive tillers of wheat and production is related to environment and nutrition supply. In this investigation, a greater number of productive tiller/plant was demonstrated by T_8 (3.89%) and T_4 (3.69%). This advancement of effective tiller might be due to optimum moisture and available nutrients provided by poultry manure which may have created the favorable condition for wheat growth. This was supported by Simpson (1990), Eck and Stewart (1995), Mitchell and Tu (2005) and Sistani et al. (2008). The result of this investigation was related to the observations of Belefant-Miller (2007), Abbasi and Khaliq (2016).

Conclusion

Quick response of chemical fertilizer offered an instant results nevertheless it has harmful effect not only crops as well as soil health. Therefore, organic soil amendment has given emphasis in this study. Seedling survivability was found greater by the application of probitic combination, whereas potential and sustainable improvement of wheat growth with organic soil amendment was found. Regarding this findings, *Trichoderma harzianum,* green manure and vermicompost may be useful for against seedling mortality and in addition of green manure, vermicompost and poultry manure may be a worthy substitute for wheat growth. Data of this study revealed that the probiotic particularly *Trichoderma harzianum* produce healthier seedling and poultry manure exhibited the capacity of supply nutrient demand and chlorophyll synthesis for improvement in growth of wheat as compared to other manures.

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Modification of soil properties through probiotic and organic manures to enhance soil fertility and productivity

Md. Anwar Hossain[1, 2], S.M Shahinul Islam[1] and Md. Mahmodol Hasan[3*]

[1]Plant Biotechnology and Genetic Engineering Laboratory, Institute of Biological Sciences, University of Rajshahi, Rajshahi-6205, Bangladesh

[2]Directorate of Secondary and Higher Education, Dhaka-1000, Bangladesh

[3]Plant pathology Laboratory, Agronomy and Agricultural Extension Department, University of Rajshahi, Rajshahi-6205, Bangladesh

*Corresponding Authors e-mail:

anwar11nubah55@gmail.com/mahmudul742001@yahoo.com/ shahinul68@gmail.com

Abstract

Presently shifting is accepted from chemical management to organic agriculture for reducing environmental hazard and to ensure soil health for productivity. So, to attain the knowledge on probiotic and organic manures influencing the physical and chemical properties of soil, the investigation was carried out during the period from July 2016 to June 2019. There were nine treatments included in the research for soil amendments. The experiment was followed as Randomized Complete Block Design (RCBD) having three replications. At this point, along with probiotic and organic amendments, chemical fertilizer and control were used for comparative study. The foremost findings were as (1) consistent addition of probiotic and organic manures increased soil physical properties like moisture content, porosity and silt particle and decreased the bulk density, particle density and sand particles. (2) Increased some chemical properties like organic matter content and nutrients availability but decreased pH and C: N ratio. Moreover, most of the physical properties greatly modified ($p \leq 0.05$) by compost + vermicompost + green manure (T_3) while maximum parameters of chemical properties changed ($p \leq 0.05$) with poultry manure + vermicompost + green manure (T_4). Hence based on soil modification requirements, farmers can be used above mentioned treatment combinations.

Key words: Physical property, chemical property, soil amendment, probiotic and organic manure.

CURRICULUM VITAE

01. Personal detail:

Name: **Md. Anwar Hossain** Father's Name: Md. Ali Hossain Motrher's Name: Mrs. Rabaya Begum Date of Birth: 08 March 1974 Nationality: Bangladeshi Religion: Muslim Sex: Male Marital Status: Married Mobile: 01712-285255, 01712-002481 E-mail: anwar11nubah55@gmail.com	**Present address:** Assistant Professor (Agriculture) Officer on Special Duty (OSD) Directorate of Secondary and Higher Education Dhaka, Bangladesh **Permanent address:** Vill: Sailkona Bazar P.O: Nazirpur P.S: Bagatipara Dist: Natore-6410 Bangladesh

02. Educational qualification:

Name of Examination	Course Duration	Division /Class	Marks Obtained	Passing Year	Board/University
Secondary School Certificate	10	First	75.60	1989	Rajshahi
Higher Secondary School Certificate	02	First	74.10	1991	Rajshahi
Bachelor of Science in Agriculture	04	First	62.20	1995	Bangladesh Agricultural University, Mymensingh
MS in Agronomy	1.5	First	70.00	2001	Bangladesh Agricultural University, Mymensingh
Masters in Education	02	CGPA-2.80	70.00	2011	Bangladesh Open University

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