IMPROVEMENT OF YIELD AND SEED QUALITY OF SOYBEAN THROUGH INTEGRATED NUTRIENT MANAGEMENT

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IMPROVEMENT OF YIELD AND SEED QUALITY OF SOYBEAN THROUGH INTEGRATED NUTRIENT MANAGEMENT

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Dedicated to

My

Beloved Parents

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CERTIFICATE

*This is to certify that the thesis entitled, "**IMPROVEMENT OF YIELD AND SEED QUALITY OF SOYBEAN THROUGH INTEGRATED NUTRIENT MANAGEMENT**" submitted to the institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN SEED TECHNOLOGY,** embodies the result of a piece of bona fide research work carried out by **SOURAV SAHA** **Registration No.: 13-05529** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

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The Author

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ABSTRACT

The experiment was conducted during October 2019 to April 2020 to improve yield and seed quality of soybean through integrated nutrient management. The variety BARI Soybean 5 was used as the test crop. In this experiment, the treatment consisted of fourteen different levels of integrated nutrient management *viz*. T_1= no chemical fertilizer, no organic manure (control), T_2= cow dung (10 t ha^{-1}), T_3= vermi compost (5 t ha^{-1}), T_4= recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}) T_5= trichoderma compost (2 t ha^{-1}), T_6= biochar (10 t ha^{-1}), T_7= cowdung (10 t ha^{-1}) +50% RDF,T_8= cowdung(10 t ha^{-1}) + 75% RDF, T_9 = vermi compost (5 t ha^{-1}) + 50% RDF, T_{10}= vermi compost (5 t ha^{-1}) + 75% RDF, T_{11}= trichoderma compost (2 t ha^{-1}) + 50% RDF, T_{12}= trichoderma compost (2 t ha^{-1}) + 75% RDF, T_{13}= biochar (10 t ha^{-1})+ 50% RDF, T_{14}= biochar (10 t ha^{-1}) + 75% RDF. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Different levels of integrated nutrient management showed statistically significant variation on all parameters of soybean. The tallest plant (37.3, 50.67, 52.53 and 52.93 cm at 30, 50, 70 days after sowing and at harvest, respectively) was recorded from Biochar(10 t ha^{-1})+50%RDF. The maximum number of leaves $plant^{-1}$, pod length (cm), number of pods $plant^{-1}$, number of seeds pod^{-1} and thousand seed weight (g) as well as the highest seed yield (1333 kg ha^{-1}), stover yield(181 kg ha^{-1}), biological yield (1513 kg ha^{-1}), was observed from Biochar(10 t ha^{-1})+ 50% RDF. On the other hand, the lowest seed yield (639 kg ha^{-1}) was observed from T_0 (control) treatment. The highest harvest index was recorded from T_6 (biochar 10 t ha^{-1}) treatment . The highest germination 94.33% was obtained in T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) treatment.. The highest germination index, coefficient of velocity, energy of emergence, shoot length, root length, vigour index, viability was recorded in T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) treatment.. Therefore Biochar(10 t ha^{-1}) + 50% RDF may be possible to use in reducing inorganic fertilizer which will increase seed quality with lower production cost without significant yield reduction of soybean.

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LIST OF ACRONYMS

AEZ	=	Agro- Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centi-meter
cv.	=	Cultivar
DAT	=	Days after transplanting
^{0} C	=	Degree Centigrade
DF	=	Degree of freedom
EC	=	Emulsifiable Concentrate
et al.	=	and others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram
HI	=	Harvest Index
HYV	=	High yielding variety
hr	=	hour
IRRI	=	International Rice Research Institute
Kg	=	kilogram
LV	=	Local variety
LYV	=	Low yielding varieties
LSD	=	Least significant difference
m	=	Meter
m^2	=	meter squares
MPCU	=	Mussorie phos-coated urea
MV	=	Modern variety
mm	=	Millimeter
viz.	=	namely
N	=	Nitrogen
ns	=	Non significant
%	=	Percent
CV %	=	Percentage of Coefficient of Variance
P	=	Phosphorus
K	=	Potassium
ppm	=	Parts per million
PU	=	Prilled urea
SAU	=	Sher-e- Bangla Agricultural University
S	=	Sulphur
SCU	=	Sulphur coated urea
t ha^{-1}	=	Tons per hectare
UNDP	=	United Nations Development Program
USG	=	Urea supergranules
Zn	=	Zinc

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* L.*)* belongs to the family Leguminosae, sub-family papilionidae is one of the leading oil and protein containing crops of the world. The crop is cultivated to 119 million ha worldwide, with a total annual production of 319 MMT (FAO,2020) As a grain legume crop it is gaining an important position in the agriculture of tropical countries including India, Sri Lanka, Thailand and Bangladesh. In Bangladesh, soybean is called the Golden bean. It is considered as miracle crop of 20th Century on account of having high protein and oil content. It contains lysine comparable with cow milk. Soybean oil is either directly used as edible oil or for manufacturing of vanaspati ghee. It is widely used in variety of foods and also in production of different antibiotics. Tripsin inhibitor is a major anti–nutritional factor in soybean. The seeds of soybean contain 42-45% protein as well as 22% edible oil (Mondal *et al*., 2002) and 24-26% carbohydrate (Gowda and Kaul, 1982), nutritional superiority on account of containing essential amino acids, unsaturated fatty acids and carbohydrates (Pawar *et al*., 2011).The soybean oil is cholesterol free and is an easily acceptable diet. Soybean accounts for approximately 50 % of the total production of oilseed crops in the world (FAO, 2007). As a grain legume, it is gaining important position in the agriculture of tropical countries including Bangladesh.. In Bangladesh, the area coverage of soybean is 151407 acres and the annual production is 104761 tons with an average yield of 1.71 t ha^{-1} (BBS, 2020).

Among the production factors affecting crop yield, nutrient is the single most important factor that plays a dominant role in yield increase if other production factors are not limiting. It is reported that chemical fertilizers today hold the key position to enhance crop production (BARC, 1997). Nutrient imbalance can be minimized by judicious application of different fertilizers. There is need to develop appropriate management technique to evaluate the performance and to assess the nutrient requirement for soybean cultivation in the country.

Vermicompost are effective organic fertilizers and bio control agents that have organic nutrition role and increase plants growth (Simsek, 2011; Arancon *et al*., 2005). Vermicompost is the microbial composting of organic wastes through earthworm activity to form organic fertilizer which contains higher level of organic matter, organic carbon, total and available N, P, K and micronutrients, microbial and enzyme activities (Parthasarathi *et al*., 2007; Ranganathan, 2006; Edwards and Bohlen, 1996). Application of vermicompost is a sustainable technology capable that improve plants growth and yield of them (Castillo *et al*., 2010). Simsek (2011) concluded that vermicompost can improve food quality and safety. Arancon *et al*. (2005) reported vermicompost contain most nutrients in the available forms such as nitrates, phosphates, exchangeable calcium and soluble potassium that have vital role for plants. Several workers (Banu *et al*., 2008; Zaller, 2007; Ranganathan, 2006) observed that integration of vermicompost with inorganic fertilization tended to increase the yield of crop viz. tomato, potato, rapeseed, groundnut, blackgram, paddy, mulberry and marigold.

An understanding of the chemical changes that occur in biochar-amended soils is key in managing agricultural soils. This is particularly of importance because the application of biochar to soils as an amendment has shown a number of physico-chemical advantages and disadvantages. For example, several studies have provided encouraging evidence that biochar adds basic cations to soils, improves soil water retention, and has liming potential of acid soils (Glaser *et al*. 2002; Laird *et al*., 2010; Sohi *et al*., 2010; Van Zwieten *et al*., 2010a).).

Biochar has also shown the ability to change soil biological community composition and abundance (Lehmann, 2011). Atkinson (2010) summarises mechanisms that affect the application of biochar in soils of the temperate zone.

The current emphases are on organic agriculture in order to mitigate climate change and increase carbon sequestration. Yields have increased with the application of organic matter (OM) in both cereal and horticultural crops

(Aliyu, 2009; Abdullahi and Lombin, 1978). Trials with organic matter on the performance of legumes, particularly on soybean are few. Chiezey and Odunze (2009) found that the application of 1 t ha^{-1} of poultry manure significantly increased the grain yield of soybean. Most recommended rates of OM range between 3-15 t ha^{-1} which is quite high and may not be easily generated by small-scale farmers. Similarly, alternative uses of OM for fencing, thatching and livestock, feed and fuel may preclude their uses for soil amendment. Rather, the emphasis should be on the complementary roles of organic matter with inorganic fertilizers for crop use.

Sustainability in crop yield and soil health could be achieved by the application of mineral fertilizers along with organic manures. Benefits of organic manures like cowdung, farm yard manure, green manures, poultry manure, biochar, Trichoderma compost and vermicompost are well known but the availability is reducing day by day. These organic manures are not only good sources of nutrients but also improve the physical structure of the soil. Apart from containing NPK these also contain small amounts of trace elements especially boron, copper, iron, sulphur, zinc and with fair quantity of growth promoting substances. Integrated nutrient management involving both the organic and inorganic source is essential to realize higher yield potential. Seeds are basically useless if they do not produce healthy, strong plants when planted. As a result, good seed is a must for seed production. The quality of the seeds sown is critical to the successful production of any crop. The information on the effect of integrated nutrient management on soybean seed production and its seed quality is meager and scanty. Keeping all the points in mind mentioned above, the present piece of research work was under taken with the following objectives.

i. To optimize the nutrient requirement for increasing the yield and seed quality of soybean

ii. To determine the most effective combination between inorganic fertilizer and organic fertilizer on yield and seed quality of soybean

CHAPTER II

REVIEW OF LITERATURE

Soybean is one of the leading oil and protein containing crops of the world. The crop has conventional less attention by the researchers on various aspects because normally it grows with minimum care or management practices. However, researches are going on in home and abroad to maximize the yield of soybean with different management practices especially on NPK fertilizer, spacing, variety, weeding, biofertilizers etc. But research works related to improvement of seed quality and yield of soybean through integrated nutrient management are limited in Bangladesh context. However, some of the important and informative works and research findings related to the integrated nutrient management so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Effect of integrated nutrient management on seed quality and yield of soybean

2.1.1 Effect of inorganic fertilizer on seed quality and yield of soybean

The soybean seed yield was significantly increased with the application of sulphur @ 20 kg ha^{-1} (2534 kg ha^{-1}) compared to sulphur levels; 30 kg ha^{-1} (2494 kg ha^{-1}), 40 kg ha^{-1} (2376 kg ha^{-1}) and 10 kg ha^{-1} (2226 kg ha^{-1}) (Hosmath *et al*., 2014). Application of different levels of sulphur showed significant effect on yield and yield attributes of soybean. In case of S, the positive response was observed only upto 20 kg S ha^{-1}. Application of sulphur @ 20 kg S ha^{-1} gave rise to the highest number of pods $plant^{-1}$ (30.07), number of seeds $plant^{-1}$ (84.94), thousand seed weight (94.61 g), and in turn produced highest seed yield (2.29 t ha^{-1}) (Akter *et al*., 2013). The levels of sulphur @ 30 kg ha^{-1} showed significantly highest content and uptake in grain and stover (Yadav *et al*., 2013).

Application of 30 kg S $ha^{-1}$and 2.5 kg Zn ha^{-1} with fertilizer dose of 30:75:0 kg NPK ha^{-1} recorded higher seed yield and straw yield. Total uptake of nutrients and micronutrients was recorded significantly highest in same treatment after harvest of crop (Pable and Patil, 2011).

Soybean was grown with 40 kg N ha^{-1} produced the tallest plant (34.18 cm) and with 0 kg N ha^{-1} treatment produced the shortest plants (30.01cm). Application of 54 kg P ha^{-1} produced the tallest plant (34.26 cm) and 0 kg P ha^{-1} the shortest plants (30.95cm). The highest plant height (36.88 cm) was obtained from the highest level of N and P, whereas, the lowest plant height (27.77 cm) was obtained from the combination of 0 kg N with 36 kg P ha^{-1} (Begum *et al.*, 2015).

Application of sulphur @ 20 kg ha^{-1} produced the highest plant height, seed yield, 1000 seed weight and straw yield (Farhad *et al*., 2010).

The grain yield of soybean increased by 23.1 and 30.5% over the control with application of 7.5 and 15.0 kg S/ha, respectively. The availability of Zn, Cu, Fe and Mn in soil, and the concentrations of these nutrients increased significantly due to S application (Manchanda *et al.*, 2006).

Nutrient availability was significantly influenced by the addition of S compared to the control. The availability of N, P, K and S was the highest at 30 kg S ha^{-1} (Vijayapriya *et al*., 2005).

There are significant effects of sulphur and nitrogen, when applied together, on the growth characteristics, yield components, and seed and oil yield. Maximum response was observed with treatment with 40 kg S and 43.5 kg N ha^{-1}. The results obtained in these experiments clearly suggest that balanced and judicious application of nitrogen and sulphur can improve both seed and oil yield of soybean cultivars by enhancing their growth (Arshad *et al.,* 2005).

Available N and S contents in the soil also increased with increasing S levels applied to soybean (Gokhale *et al*., 2005).

Boron is considered as an essential element for plant growth and development. Sexual reproduction in plant is more sensitive to low B, than vegetative growth **(**Ahmad *et al***.,** 2009).

Foliar application with boron and yeast extract either individually or in a mixture, significantly stimulate many growth aspects as number of leaves per plant, dry weights of both stems and leaves per plant, total leaf area and absolute growth rate as compared with the control treatment (El-Yazied and Mady., 2012).

The optimum concentration of boron needed to mitigate the harmful effect of salinity at early establishment of seedlings including seed germination (Arora *et al*., 2012).

P and B treatments significantly affected soybean growth, and there were significant interactions between P and B. Among which, P availability was the primary factor on soybean growth and B uptake. At the same B level, increasing P availability could significantly increase soybean plant dry mass, grain yield and P, B uptake. At the normal P level, increasing B availability only increased plant dry mass and P, B uptake of the P efficient genotypes, but not the P inefficient genotypes, particularly at mature stage. Improving B status could significantly increase the yield of P efficient soybean genotypes (Huang *et al*., 2012).

Combined application of boron (1.0 ppm) and zinc (0.10 ppm) after 20 and 40 days of sowing of the seeds was found to be beneficial for growth in terms of plant height, leaf number, branch number and shoot weight, earliness, yield in terms of number, length, fresh weight, dry weight and percent dry matter of pod and number of seeds per pod (Rajni and Meitei, 2004).

The micronutrients boron have shown significant impact on plant metabolism absorption and translocation of materials synthesis of essential macro and micro molecule and enzyme synthesis and their activity regulation (Singh *et al.*, 2011).

Soybean yield attributed viz., pods/plant, seeds/pod and hundred seed weight were increased significantly by the addition of boron and FYM at the fertility levels of 50% and 100% NPK (Chaturvedi *et al.*, 2012).

The application of 1.5 kg B ha^{-1} were found to be the optimum levels of boron for obtaining maximum yield attributes (Devi *et al.*, 2012).

Application of 2.0 kg ha^{-1} B recorded better yield attributes (branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1} and 100 seed weight and higher yield) than the other treatments (Singh *et al.*, 2012).

On the other hand Application of B did not influence soybean yield in any application stage and the yield components (pod number $plant^{-1}$, grain number pod $^{-1}$, grain weight) did not differ significantly with application to leaf spraying of B, probably due to their adequate content in soil and water availability during the growing season (Seidel and basso, 2012).

2.1. 2 Effect of biochar on seed quality and yield of soybean

Application of biochar with inorganic fertilizer shows no significant effect during the first year of application. However, the maize yield gradually increased with an increase in the biochar application rate in the ensuing years. These yield increases were as a result of increases in pH and nutrient retention. It was found that there was a stark overall decline in yield in the fourth year of application due to the decreasing Ca and Mg soil stocks (Major *et al.*, 2010).

Biochar treated plots improved nitrogen use efficiency by 38% compared to plots without biochar (Kawsar *et al.*, 2015).

Biochar appears to be an effective method of supplying phosphorus (P), potassium (K), and increasing soil pH, and there was no effect on nitrogen availability (Zee *et al.*, 2017).

Biochar improve the growth of wheat seedling, for mild saline alkali soil and normal soil. Biochar had no obvious effect on the growth of wheat seedling (Wang and Xu, 2013).

The application of rice straw biochar might be effective in immobilization of metal in the soil and reducing its uptake and translocation to grains (Abbas *et al*., 2017).

Biochar retains nutrients and water to improve wheat productivity. Hence, the biochar produced from *Prosopis juliflora* could be used for wheat productivity improvement (Gebremedhin *et al.,* 2015).

However, although the liming ability of biochar has shown positive responses due to increased biomass production and yields (Lehmann *et al*., 2003; Rondon *et al*., 2007; Vaccari *et al*., 2011; Van Zwieten *et al*., 2007), negative yield responses have also been found because high soil pH values are often associated with micronutrient deficiencies (Mikan and Abrams, 1995).

The addition of biochar also significantly increases the content of available water in the soil by increasing the amount of water retained in the soil (field water capacity) and allowing plants to draw the soil water content and lower it before wilting (Koide *et al.,* 2015). This is caused mainly due to increasing capillary water capacity of the soil after application of biochar. This leads to increased productivity of plant cultivation, increased microbial activity in soil, and higher levels of availability of nutrients, particularly P and K (Biedermann and Harpole, 2013).

2.1.3 Effect of vermicompost on seed quality and yield of soybean

Vermicompost significantly affected to the number of branches, number of pods and seed weight (Aritonang and Sidauruk, 2020).

Application of zinc and vermicompost showed a significant effect on the growth parameters and macro and micronutrients uptake by the plant (Purna *et al*., 2020).

Applications of vermicompost singly or in combination with other organic fertilizer have been proved effective to enhance growth and yield of various plants like Soybean and other crops and yield of them increased (Javed and Panwar, 2013).

Application of vermicompost fertilizer and mycorrhiza decreased the toxic effects of cadmium chloride. By application of vermicompost fertilizer plant height, chlorophyll content and carotenoid leaf was increased and application of mycorrhiza increased leaf soluble protein significantly (Yadavi *et al.,* 2014).

The use of vermicompost in field crops, vegetables, flowering plants and fruit crops has increased the yield and improved the quality with less disease and pest incidence (Baphna *et al.,* 1992).

The water holding capacity and electrical conductivity of the soil were increased in the plots supplied with 5.0 t vermicompost per ha compared to control plots (Jadhav *et al*., 1993).

The organic carbon content of the soil increased by 0.27 percent due to application of vermicompost compared to application of chemical fertilizer alone (Hapse *et al.,* 1993).

Application of vermicompost @ 5 t ha^{-1} in scented rice Pusa Basmati-1 resulted in significantly higher yield (4889 kg ha^{-1}) as compared to no vermicompost application (Murali and Setty, 2004).

Increased availability of nutrients in vermicompost compared to non-ingested soil resulted in significantly better growth and yield of rice has been reported by several workers (Sudhakar, *et al*., 2002).

Apart from the improvement in fertilizer use efficiency, vermicompost ensured a steady supply of secondary nutrients like Mg as well as micronutrients throughout the growth period, which improved the chlorophyll content of leaves and reduced the chaff percentage. Unlike other organic manures, vermicompost addition has got the added advantage of quick nutrient absorption by plants, to result in better dry matter accumulation (Sudha and Chandini, 2003).

Conjuctive use of vermicompost @ 2 t/ha along with 50 per cent N/ha enabled hybrid rice to produce grain yield on par that obtained by application of recommended dose of fertilizer along (Upendrarao and Srinivasulureddy, 2004).

Vermicomposting is the bioconversion of organic waste materials into nutritious compost by earthworm activity and is an important component of organic farming package (Meena *et al.,* 2003).

Application of vermicompost improved the chemical and physical structures of the soil. Application of vermicompost increased the infiltration and reduced run-off and thus increased soil water availability for plant growth (Anitha and Prema *et al.,* 2003).

The soil organic carbon content increased with the treatment receiving potato vermicompost over the control. Availability of nitrogen increased in earthworm cast application as compared to non-ingested soil (Vasanthi and Kumaraswamy, 1999).

2.1. 4 Effect of Trichoderma on seed quality and yield of soybean

Single and combined applications of Trichoderma strains and their bioactive metabolites (BAMs) harzianic acid (HA), 6-pentyl-α-pyrone (6PP), and hydrophobin1 (HYTLO1) effect on the growth, yield, and nutrient uptake of soybean plants. Significant promotion of plant growth (up to 39%), as well as an increase in mineral content, was achieved with BAMs, used alone or combined with T. harzianum. Interestingly, the treatments also increased the level of fatty acids (oleic, linolenic, 11-eicosenoic, and stearic) (Roberta Marra *et al.*, 2019).

Seed treatment with T. harzianum and T. hamatum can enhance percentage and early germination in soybean seeds (Mukhtar *et al.,* 2012) .

2.1.5 Effect of organic manure on seed quality and yield of soybean

The application of FYM + vermicomopst (50 % each) + Jeevamrut 2 times (30 and 45 DAS) to soybean recorded significantly higher values for growth, yield attributes and yield of soybean. The application of FYM + vermicomopst (50 % each) + Jeevamrut 2 times (30 and 45 DAS) showed higher protein and oil content in soybean grain than rest of the treatments used. The total uptake of nitrogen, phosphorus and potassium by soybean was significantly higher due to application of FYM + vermicomopst (50 % each) + Jeevamrut 2 times (30 and 45 DAS) to soybean. The net monetary return was recorded maximum under FYM + vermicompost (50 % each) + jeevamrut 2 times (30 and 45 DAS) followed by jeevamrut 2 times (30 and 45 DAS) and B:C ratio was higher where jeevamrut applied to soybean 2 times (30 and 45 DAS).Application of FYM + vermicompost (50 % each) + jeevamrut 2 times (30 and 45 DAS) to soybean recorded enhanced microbial count viz., fungi, bacteria and actinomycetes followed by application of FYM + vermicompost (50 % each) soybean (Pati and Udmale, 2016).

The nodulation and growth of soybean effects by different rates of nitrogen and phosphorous. The highest plant height (70.05 cm) of soybean can be obtained by application of 50 kg/ha nitrogen, 125 kg/ha phosphorus and 75 kg/ha potassium (Sutharsan *et al.*, 2016).

Application of 2.5 t ha^{-1} poultry manure and 150 kg ha^{-1}.NPK gave the highest plant height (70.9 cm). The minimum plant height of (46.0 cm) was observed with the control (no fertilizers) (Falodun *et al.*, 2015).

An on farmer's fields (twelve farmers)' study was carried out by (Zoundji *et al.*, 2015) in Northern and Centre Benin to determine the effectiveness of Bradyrhizobium japonicum strains introduced in Benin cropping systems with five inoculations treatments (control, FA3, STM 3043, STM 3045 and USDA 110) and two phosphorus levels (0 and 50 kg of P_20_5 ha^{-1}). Each farmer represented one replication. Results indicated that, in AEZ 3, STM3043 strain combined to 50 kg of P_20_5 ha^{-1} had the maximum height (93 cm $plant^{-1}$) with a gain of 52% compared to the control. In AEZ 5, the height of soybean plants varied from 36 cm (control + 0 kg of P_20_5 ha^{-1}) to 88 cm (STM 3043 + 50 kg of P_20_5 ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from October, 2019 to April 2020 to study the improvement of seed yield and quality of soybean through integrated nutrient management. This chapter includes materials and methods that were used in conducting the experiment are presented below under the following headings:

3.1 Experimental site

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude.

3.2 Soil characteristics

The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The soil was having a texture of sandy loam with pH and Cation Exchange capacity 5.6 and 2.64 meq 100 g $soil^{-1}$, respectively. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are given in Appendix I.

3.3 Climate condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department.

3.4 Planting material

The variety BARI Soybean 5 was used as the test crop. The seeds were collected from the Agronomy Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.5 Land preparation

The land was irrigated before ploughing. After having ‘joe’ condition the land was first opened with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by 3 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 19th and 23th October, 2019, respectively. Experimental land was divided into unit plots following the design of experiment.

3.6 Treatments of the experiment

The experiment comprised of one factor

Treatment combinations:

T_1= No chemical fertilizer, no organic manure (Control)

T_2= cow dung (10 t ha^{-1})

T_3= vermi compost (5 t ha^{-1})

T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1}, TSP 150 kg ha^{-1} , MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1})

T_5= Trichoderma compost (2 t ha^{-1})

T_6= Biochar (10 t ha^{-1} ha^{-1})

T_7= Cowdung (10 t ha^{-1}) + 50% RDF

T_8= Cowdung (10 t ha^{-1})+75% RDF

T_9= Vermi compost (5 t ha^{-1})+ 50% RDF

T_{10}= Vermi compost (5 t ha^{-1}) + 75% RDF

T_{11}= Trichoderma compost (2 t ha^{-1}) + 50% RDF

T_{12}= Trichoderma compost (2 t ha^{-1}) + 75% RDF

T_{13}=Biochar (10 t ha^{-1}) + 50% RDF

T_{14}=Biochar (10 t ha^{-1}) + 75%RDF

3.7 Experimental design and layout

The experiment was laid out in one factors Randomized Complete Block Design with three replications. The layout of the experiment was prepared for distributing the combination of different combination of nutrient levels. Thus there were 42 unit plots each of 2m × 3m size. The 14 treatments of the experiment were assigned at random in 14 plots of each block, representing a replication (Appendix III).

3.8 Sowing of seeds in the field

The seeds of soybean were sown on October 29, 2019 in solid rows in the furrows having a depth of 2-3 cm and row to row distance was 30 cm and plant to plant 5-6 cm.

3.9 Fertilizer application

Urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, boric acid and molybdenum were used as a source of nitrogen, phosphorous, potassium, sulphur and boron, respectively. The fertilizers urea, TSP and MoP were applied at the rate of 60, 175 and 120 kg hectare^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation. All organic and inorganic fertilizer were applied as per treatment of the experiment. All of the fertilizers were applied in broadcast during final land preparation.

3.10 Intercultural operations

3.10.1 Thinning

Seeds started germination within four days after sowing (DAS). Thinning was at 23 DAS to maintain optimum plant population in each plot.

3.10.2 Irrigation and weeding

Irrigation was provided two times at 25 DAS and 55 DAS for all experimental plots equally. The crop field was weeded at 23 DAS and 52 DAS.

3.10.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 ml with 1 litre water for two times at 15 days interval after seedlings germination to control the insects.

3.11 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Plant height and number of branches plant^{-1} were recorded from selected plants at an interval of 10 days started from 30 DAS to 60 DAS and at harvest.

3.12 Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown in color**.** The matured pods were collected by hand picking from the area of 6 m^2 of each plot.

3.13 Data collection

The following data were recorded

i. Growth
   a. Plant height(cm)
   b. Number of leaves plant^{-1}

ii. Yield contributing characters
   a. Number of pods plant^{-1}
   b. Shoot and root length(mm)
   c. Pod length (cm)
   d. Number of seeds pod^{-1}
   e. Weight of 1000 seeds

iii. Yield
   a. Seed yield (kg ha^{-1})
   b. Stover yield (kg ha^{-1})

c. Biological yield (kg ha^{-1})

d. Harvest index(%)

iv. Seed quality

a. Total Germination (TG %)

b. Mean germination time (MGT)

c. Germination index (GI)

d. Coefficient of velocity (CV)

e. Energy of emergence (EG%)

f. Vigour Index (VI)

g. Seed viability(%)

3.14 Procedure of data collection

3.14.1 Growth

a) Plant height (cm)

The plant height was measured at 30, 50, 70 DAS and at harvest with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

b) Number of leaves $plant^{-1}$

The total number of leaves $plant^{-1}$ was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 30, 50, 70 DAS.

3.14.2 Yield contributing characters

a) Shoot and root length (mm)

Randomly selected 6 seedlings from each treatment were collected and cotyledons were removed from them. Shoot and root length were measured with a ruler and accuracy of measurement was 1 mm.

b) Pod length(cm)

Pod length was taken of randomly selected ten pods and the mean length was expressed on pod^{-1} basis.

c) Number of pods $plant^{-1}$

Numbers of total pods of selected plants from each plot were counted and the mean numbers were expressed as $plant^{-1}$ basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

d) Number of seeds pod^{-1}

The number of seeds $pods^{-1}$ was recorded from randomly selected 10 pods at the time of harvest. Data were recorded as the average of 10 pods from each plot.

e) Weight of 1000 seeds (g)

One thousand cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram.

3.14.4 Yield

a) Seed yield (Kg ha^{-1})

The seeds collected from 6 (3 m ×2 m) square meter of each plot were cleaned. The weight of seeds was taken and converted the yield in kg ha^{-1}.

b) Stover yield (Kg ha^{-1})

Stover obtained from each unit plot was sun-dried and weighed carefully. The dry weight of stover of central 1 m^2 area and five sample plants were added to the respective stover yield m^{-2} and finally converted to kg ha^{-1}.

c) Biological yield (Kg ha^{-1})

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Stover yield.

c) Harvest index(%)

Harvest index was calculated from the seed and stover yield of soybean for each plot and expressed in percentage.

$$HI = \frac{\text{Economic yield (seed weight)}}{\text{Biological yield}} \times 100$$

3.14.5 Seed quality

a) Total germination (TG%)

Total germination (TG) was calculated as the number of seeds which was germinated within total days as a proportion of number of seeds shown in each treatment expressed as a percentage (Othman *et al*., 2006).

$$TG\ (\%) = \frac{\text{Number of germinated seed}}{\text{Total number of seed set for germination}} \times 100$$

b) Mean germination time (MGT)

Mean germination time (MGT) was calculated according to the equation of Moradi Dezfuli *et al*. (2008).

$$MGT = \frac{\sum Dn}{\sum n}$$

Where,

n = number of seeds germinated on day D, and

D = number of days counted from the beginning of germination.

c) Germination index (GI)

Germination index (GI) was calculated as described in the Association of Official Seed Analysts (1983) as the following formulae:

$$GI = \frac{\text{Number of germinated seed}}{\text{Days of first count}} + \ldots + \frac{\text{Number of germinated seed}}{\text{Days of final count}}$$

d) Coefficient of velocity (CV)

Coefficient of velocity = (number of germinated seeds per day) is measured according to the method described by Scott *et al*. (1998).

$CV = 100 \times (\sum Ni / \sum Ti\ Ni)$

Where,

Ti= number of days after sowing and

Ni = number of seeds germinated on ith day.

e) Energy of emergence (EG%)

Energy of emergence (EG) was recorded on the 4th day after placement of seeds. It is the percentage of germinating seeds 4 days after planting relative to the total number of seeds tested (Ruan *et al*., 2002a). Energy of emergence expressed in percentage.

f) Vigour Index (VI)

Vigour Index (VI) was calculated from total germination and seedlings length by using the formula of Abdul- Baki and Anderson (1970).

$$VI = \frac{TG\ (\%) \times \text{seedling length (mm)}}{100}$$

Here, TG = total germination.

g) Seed viability (%)

Carried out with two sub-samples of 50 seeds for each treatment and replication, which were preconditioned on paper towels moistened with distilled water for 16 hr in a germinator set at 25°C ± 2°C. After this period, the seeds were transferred to plastic cups (50 mL) and were completely submerged in 0.075% tetrazolium solution for three hours, in an incubator set at 40°C in the dark. After staining, the seeds were classified for viability at levels from 1 to 8, according to the criteria proposed by França-Neto *et al.* (1998). The germination potentials were expressed as a percentage.

3.15 Statistical analysis

The data obtained for different characters were statistically analyzed using MSTAT-C software to observe the significant difference among the different nutrient management. The mean values of all the characters were calculated and factorial analysis of variance was performed. The significance of difference among the treatment means was separated by Duncan`s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez ,1984).

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted to improvement of yield and seed quality of soybean through integrated nutrient management. Data on different growth parameter, yield was recorded. The findings of the experiment have been presented and discussed with the help of table and graphs and possible interpretations were given under the following headings:

4.1 Growth contributing characters

4.1.1 Plant height(cm)

Plant height of BARI soybean 5 showed statistically significant variation due to different levels of nutrient management at 30, 50, 70 days after sowing (DAS) and at harvest. Data revealed that at 30, 50, 70 DAS and at harvest, the tallest plant (37.3, 50.67, 52.53 and 52.93 cm at 30, 50, 70 DAS and at harvest, respectively) was recorded from T_{13} (Biochar 10 t ha^{-1}+50% RDF), whereas the shortest plant (30.73, 44.34, 46.93 and 47.67 cm at 30, 50, 70 DAS and at harvest, respectively) was found from T_1 (Control) treatment (Table 1). The increase in plant height due to application of increased level of fertilizer and manure might be associated with stimulating effect of nitrogen on various physiological processes including cell division and cell elongation of the plant. In general, plant height increased with the increasing level of ingoranic with organic matter. The significant increase in plant height observed by plants treated with fertilizer may be attributed to internodes elongation and other nutrients received by the plant from both organic and inorganic sources. This observation confirms the findings of Falodun *et al*. (2015) and Khaim *et al*. (2013). Falodun and Osaigbovo (2010) also reported that nutrients in inorganic are readily available for plant uptake upon application while the organic forms of nutrients are slowly available. So there is a continuous supply of nutrient to the plant up to maturity. Further Patil and Udmale (2016) reported that the increase in plant height due to organic inputs might be attributed to increase in the availability of cytokinine to shoot which in turn play a role in cell elongation process either through cell division or cell elongation.

Table 1. Effect of integrated nutrient management on plant height of soybean at different days after sowing

Treatments	Plant height (cm)at			
	30 DAS	50 DAS	70 DAS	harvest
T_1	30.73 b	44.34 c	46.93 d	47.67 b
T_2	33.93 ab	47.81 abc	48.53 bcd	49.67 ab
T_3	32.50 ab	47.53 abc	47.33 cd	47.67 b
T_4	34.77 ab	46.79 abc	49.87 abc	50.67 ab
T_5	36.67 a	44.73 bc	49.60 a-d	50.00 ab
T_6	33.53 ab	48.60 abc	51.87 a	52.33 a
T_7	33.70 ab	46.93 abc	50.13 abc	50.67 ab
T_8	34.57 ab	48.47 abc	51.67 a	52.33 a
T_9	32.70 ab	50.00 abc	51.07 ab	52.00 a
T_{10}	34.57 ab	49.57 abc	50.60 ab	51.33 a
T_{11}	35.60 ab	47.70 abc	50.47 ab	51.00 ab
T_{12}	33.57 ab	50.53 ab	51.93 a	52.33 a
T_{13}	37.30 a	50.67 a	52.53 a	52.93 a
T_{14}	35.27 ab	48.33 abc	52.20 a	52.77 a
SE value	4.87	5.01	2.59	3.15
CV (%)	8.48	6.22	5.75	5.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

4.1.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} of soybean was varied significantly due to different levels of integrated nutrient management. The maximum number of leaves plant^{-1} (8.87, 29.13, 16.20 cm at 30, 50, 70 DAS, respectively) was obtained from T_{13} (Biochar 10 t ha^{-1} +50%RDF) and the minimum number leaves (6.80, 14.40, 10.13 cm at 30, 50, 70 DAS, respectively) was observed from T_1 (control) treatment (Table 2).

4.2 Yield contributing characters

4.2.1 Pod length (cm)

Statistically significant variation was recorded due to different levels of integrated nutrient management in terms of pod length of soybean. The longest pod (3.56 cm) was observed from T_{13} (Biochar 10 t ha^{-1} + 50% RDF), which were statistically identical from other treatment, while the shortest pod (2.89 cm) was found from T_1 (Control) treatment (Table 3).

4.2.2 Number of pods plant^{-1}

Different levels of integrated nutrient management showed statistically significant variation on number of pods plant^{-1} of soybean. The maximum number of pods plant^{-1} (47.80) was recorded from T_{13} (Biochar 10 t ha^{-1} +50%RDF) treatment. Whereas the minimum number of pods plant^{-1} (27.53) was obtained from T_1 (control) treatment, which was statistically similar with T_{10}(Vermi compost 5 t ha^{-1} + 75%RDF) treatment (Table 3).The application of organic amendments and chemical fertilizer possibly accumulated more nutrients during the critical plant growth period and higher available P contributed to the developing seed numbers. There seemed to be less nutrient ability in the control plots resulting in low pod numbers. Begum *et al.* (2015) observed that increasing phosphorus rate increased the number of pods plant^{-1}. Soybean seed inoculation by rhizobial bacteria (Kazemi *et al*., 2005) and B. japonicum bacteria (Zhang *et al*., 2003) was also increased pods per plant. This result was supported by Myint *et al*. (2009) and

Manalo *et al*. (1998) who considered that biofertilizer significantly increased the number of pods plant^{-1}.

Table2. Effect of integrated nutrient management on number of leave per plant soybean at different days after sowing

Treatments	Number of leaves plant^{-1} at					
	30 DAS		50 DAS		70 DAS	
T_1	6.80	b	14.40	d	10.13	b
T_2	8.40	ab	16.33	cd	11.53	b
T_3	7.40	ab	15.93	cd	12.00	ab
T_4	7.80	ab	19.00	cd	13.87	ab
T_5	7.60	ab	18.67	cd	13.60	ab
T_6	7.53	ab	18.40	cd	13.47	ab
T_7	7.80	ab	26.60	ab	14.00	ab
T_8	7.27	ab	18.87	cd	13.00	ab
T_9	7.53	ab	21.60	bc	13.47	ab
T_{10}	7.60	ab	18.07	cd	10.53	b
T_{11}	7.73	ab	19.93	cd	13.33	ab
T_{12}	7.73	ab	17.93	cd	13.27	ab
T_{13}	8.87	a	29.13	a	16.20	a
T_{14}	8.73	a	17.53	cd	13.00	ab
SE value	1.62		5.51		3.88	
CV (%)	14.53		8.22		6.06	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

4.2.3 Number of seeds pod^{-1}

Different levels of integrated nutrient management showed statistically significant variation on number of seeds pod^{-1} of soybean. The maximum number of seeds pod^{-1} (3.13) was found from T_{13} (Biochar 10 t ha^{-1} +50%RDF), while the minimum number seeds pod^{-1} (2.47) was recorded from T_1 (Control) treatment (Table 3). This was perhaps due to a continuous supply of nitrogen, phosphorus, potassium to the crop at the early stages and through organic manure (as slow release nutrient) also at later stages of crop growth. This finding is consistence with the finding of Patil and Udmale (2016). Khaim *et al.* (2013) found highest seed plant^{-1} of soybean in S and P treated plant. Begum *et al.* (2015) observed that number of seeds pod^{-1} increased with the increase of phosphorus application.

4.2.4 Weight of 1000 seeds (g)

Weight of 1000 seeds of BARI soybean 5 varied significantly due to different levels of integrated nutrient management under the present study. The highest weight of 1000 seeds (123.90 g) was observed from T_{13} (Biochar 10 t ha^{-1} +50%RDF) ,while the lowest weight (78.73 g) was obtained from T_1 (Control) treatment (Table 3). Better 1000 grains weight depends on optimum dry matter partitioning during reproductive stage of plant. Nutrient elements from organic and inorganic sources ensure long term and optimum nutrient supply from the source to sink which ensure maximum accumulation of photosynthates to the pod; consequently increase the 1000 grain weight. Vermicompost application delayed leaf senescence and this might be the reason for increased seed weight. Better growth and development of crop plants due to phosphorus supply and nitrogen uptake might have increased the supply of assimilates to seed, which ultimately gained more weight. Similar achievements on hundred seed weight with phosphorus were observed by Begum *et al.* (2015). Akter *et al*. (2013) reported that application of different levels of S showed significant effect on yield attributes. Farhad *et al*. (2010) reported that application of S @ 20 kg ha^{-1} produced the highest 1000 seed weight.

Table 3 .Effect of integrated nutrient management on Pod length, number of pod per plant, number of seed per pod and 1000 seed weight of soybean

Treatments	Pod length (cm)		Number of pod plant^{-1}		Number of seed pod^{-1}		1000 seed weight (gm)	
T_1	2.89	e	27.53	d	2.47	c	78.73	c
T_2	3.21	a-e	30.93	cd	2.67	bc	93.40	bc
T_3	3.29	a-d	31.93	cd	2.73	abc	91.27	bc
T_4	3.14	cde	30.13	cd	2.73	abc	102.50	b
T_5	2.93	de	32.60	cd	2.93	ab	88.40	bc
T_6	3.31	abc	45.00	ab	2.53	bc	102.40	b
T_7	3.35	abc	37.33	a-d	2.80	abc	103.30	b
T_8	3.12	cde	37.13	a-d	2.93	ab	96.73	b
T_9	3.29	a-d	36.13	a-d	2.80	abc	101.10	b
T_{10}	3.25	a-d	28.20	d	2.73	abc	96.47	b
T_{11}	3.52	ab	42.47	abc	2.73	abc	100.60	b
T_{12}	3.17	b-e	35.40	bcd	2.87	abc	98.80	b
T_{13}	3.56	a	47.80	a	3.13	a	123.90	a
T_{14}	3.42	abc	39.13	a-d	2.80	abc	102.50	b
SE value	0.31		10.79		0.38		15.86	
CV (%)	5.67		7.94		8.19		5.95	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

4.3. Yield

4.3.1 Seed yield (kg ha^{-1})

Seed yield of soybean varied significantly due to different levels of integrated nutrient management. The highest seed yield (1333 kg ha^{-1}) was observed from

T_{13} (Biochar 10 t ha^{-1} +50%RDF) treatment. On the other hand, the lowest seed yield (639.30 kg ha^{-1}) was observed from T_1 (control) treatment, which was statistically similar with T_5 and T_{10} treatment (Table 4). The maximum grain yield might be attributed to maximum number of pods $plant^{-1}$, seeds $plant^{-1}$ and 1000 seed weight. This might be due to adequate supply of nutrient element at the right time from organic and inorganic sources which helped optimum dry matter partitioning from the source to sink during reproductive stage of plant that maximize accumulation of photosynthates to the pod; consequently increase the grain yield of soybean. Similar results also found by Falodun *et al*. (2015) who reported that the increase in the number of pods, pod weight and yield with the application rate of 2.5 t ha^{-1} poultry litter + 150 kg ha^{-1} NPK could be due to the rate of release of nutrients which were much higher in the inorganic fertilizers since they provided major elements at the early stage of plant growth and development. Thus, plants showed accelerated growth and organic manure in combination complements this effect at the later stage of growth. The effect of the nutrients in increasing growth and yield of onion was relatively higher when in association with one another. Bhuiyan *et al*. (1998) found that application of S at 20 kg per ha produced the highest seed yield.

4.3.2 Stover yield (Kg ha^{-1})

Levels of integrated nutrient management exerted significant variation on stover yield of soybean (Table 4). The maximum stover yield (181.00 kg ha^{-1}) was observe in T_{14} (Biochar 10 t ha^{-1}+ 75% RDF), which was statistically similar with T_{13} (Biochar 10 t ha^{-1} + 50% RDF) treatment. Again the lowest yield (111.00 kg ha^{-1}) was recorded from T_1 (Control) which was statistically at similar with T_{10} (Vermi compost 5 t ha^{-1}+ 75% RDF) treatment. This result is full agreement of Khaim *et al.* (2013) who reported that, the stover yield of soybean was maximum because poultry manure with chemical fertilizers added much of organic matter in soil, which influenced the vegetative growth of soybean plant. Dikshit and Khatik (2008) observed that application of organic and inorganic fertilizers increased the stover yield of soybean. Begum *et al.* (2015) reported that, significantly higher stover yield (2.04 t ha^{-1}) was produced by the integration of 75% RDF with vermicompost at the rate of 1 t ha^{-1} and PSB and the lowest (0.97 t ha^{-1}) from control.

4.3.3 Biological yield (kg ha^{-1})

Different levels of integrated nutrient management significantly varied on biological yield of soybean (Table 4). However, the highest biological yield (1513 kg ha^{-1}) was found in T_{13} (Biochar 10 t ha^{-1} +50%RDF) and that of the lowest 750.30 kg ha^{-1} from T_1 (Control) treatment. The result revealed that combination of integrated nutrient management increased the biological yield which might be due to the cumulative favorable effect of grain and straw yield. These findings are in accordance with the results of Khaim *et al.* (2013), who reported that biological yield was also increased in the RDCF 75% + PM 1 t ha^{-1} and CD 10 t ha^{-1} where poultry manure and cowdung were applied in decomposed form and they were identical the highest yield of RDCF 100%.

4.3.4 Harvest index (%)

Harvest index of soybean showed significant variation for different levels of integrated nutrient management (Table 4). However the highest harvest index (89.74%) was recorded from T6 (Biochar 10 t ha^{-1}) and the lowest harvest (83.66%) index was recorded from T_3 (Vermi compost 5 t ha^{-1}) treatment. These findings are contradictory with the results of Khaim *et al.* (2013), who reported that harvest index was influenced by the application of organic and inorganic fertilizer with other fertilizers. This might be due to RDCF and other organic fertilizers, which affected the biological yield and grain yield.

Table 4: Effect of integrated nutrient management on seed, stover , biological yield and harvest index of soybean

Treatments	Seed yield (kg ha^{-1})		Stover yield (kg ha^{-1})		Biological yield (kg ha^{-1})		Harvest index (%)	
T_1	639	e	111	e	750.30	e	85.21	ab
T_2	879.70	cde	129	cde	1008.70	cde	87.21	abc
T_3	810.30	de	152	a-e	962.70	de	83.66	c
T_4	1223	ab	165	abc	1388	ab	88.09	abc
T_5	728	e	117	de	845.70	e	86.19	abc
T_6	1242	ab	142	a-e	1384	ab	89.74	a
T_7	832	cde	134	b-e	966.70	de	85.68	abc
T_8	1046	bcd	133.30	b-e	1179	bcd	88.74	ab
T_9	833	cde	152.70	a-e	985.70	cde	84.60	abc
T_{10}	766	e	113.70	e	879.70	e	86.87	abc
T_{11}	1061	bcd	172.30	ab	1233	bc	85.63	abc
T_{12}	1017	bcd	157.70	a-d	1174	bcd	86.52	abc
T_{13}	1333	a	179.30	a	1513	a	88.14	abc
T_{14}	1070	bc	181	a	1251	b	85.53	abc
SE value	221.60		37.40		225.40		4.54	
CV (%)	5.71		5.28		9.11		5.33	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

4.4 Seed Quality

4.4.1 Total Germination(%)

Total Germination percentage was significantly influenced by different levels of integrated nutrient management (Figure 1). The highest germination 94.33% was obtained in T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) treatment. The lowest germination 80.00% was observed in T_1 (Control) treatment.

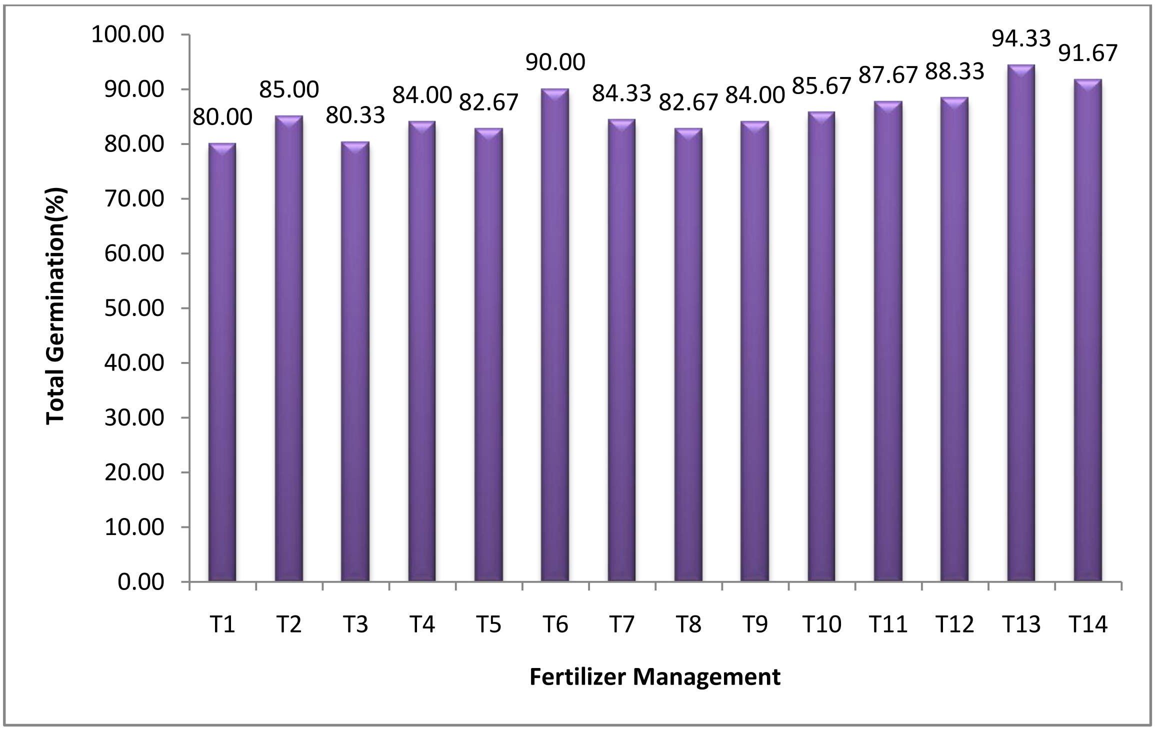

Fig. 1. Effect of different levels of integrated nutrient management on germination percentage of soybean seed. (SE=8.075)

T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

4.4.2 Mean germination time (days)

There was significant variation observed on mean germination time at different levels of integrated nutrient management (fig. 2).. The longest mean germination time 5.78 days was observed from T_{10} (Vermi compost 5 t ha^{-1} + 75% RDF) treatment. The shortest mean germination time 4.88 days was found in T_8 (Cowdung 5 t ha^{-1}+75% RDF) treatment.

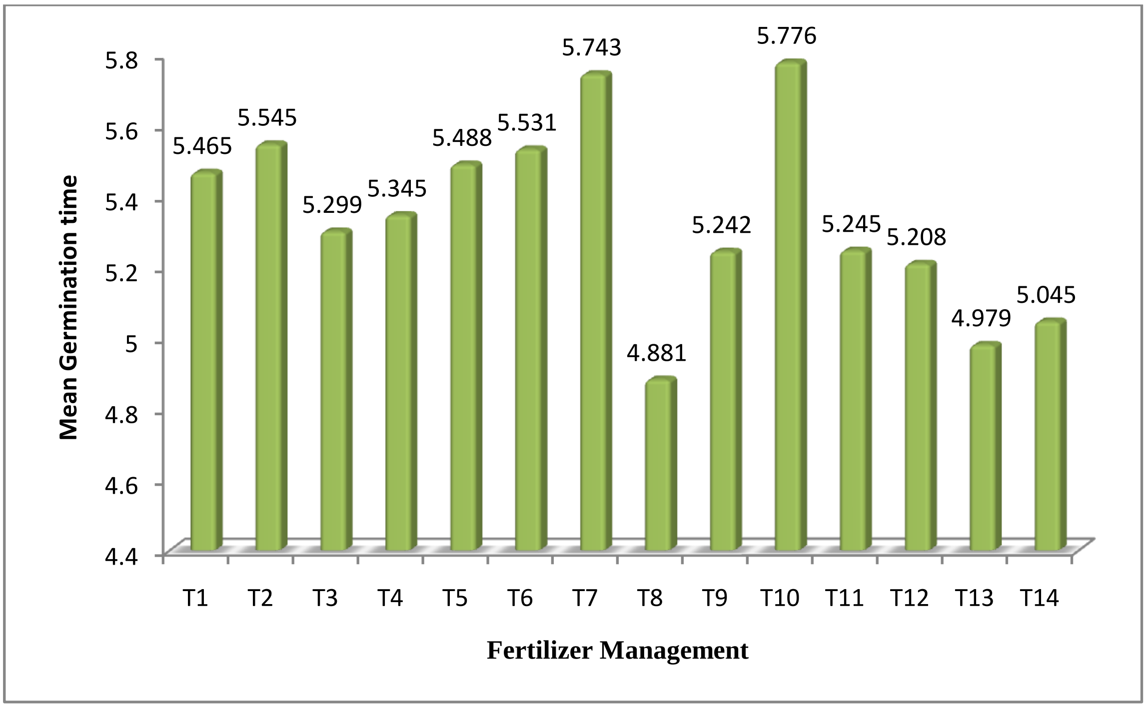

Fig.2. Effect of different levels of integrated nutrient management on Mean germination time of soybean seed (SE = 0.056)

T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

4.4.3 Germination index

Germination index showed highly significant difference at different levels of integrated nutrient management (Figure 3). The highest germination index 21.07 was recorded in T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) treatment compare to germination index 20.25 was recorded from T6 (Biochar 10 t ha^{-1}) treatment. The lowest germination index 15.55 was found in T_1 (Control) treatment.

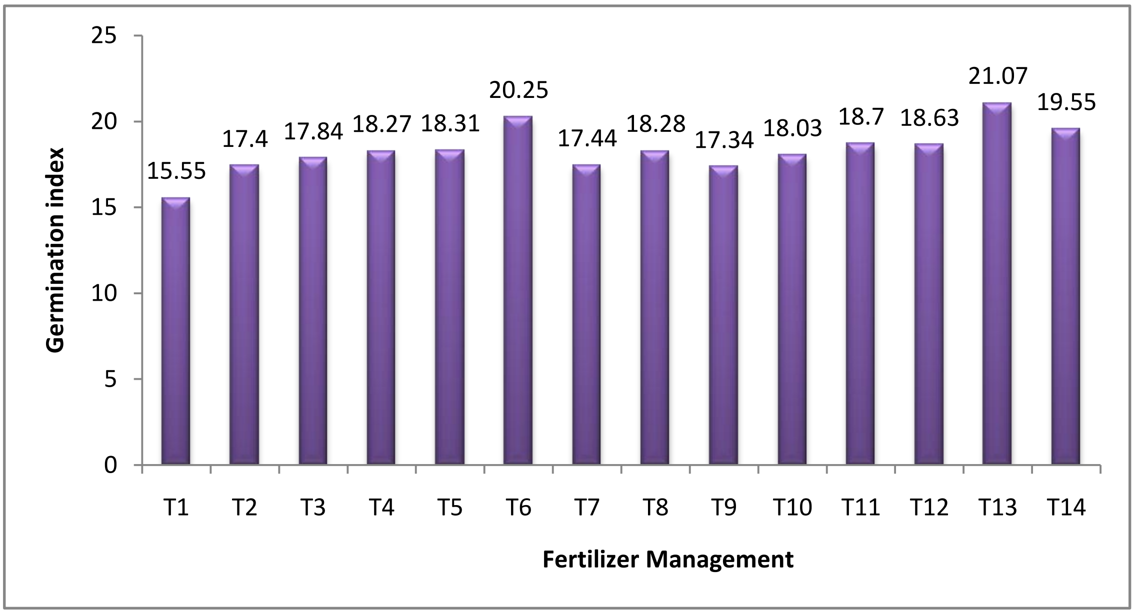

Fig. 3. Effect of different levels of integrated nutrient management on Germination index of soybean seed (SE=0.652)

T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

4.4.4 Coefficient of velocity

There was significant difference was observed among the different levels of integrated nutrient management (Table 5) on the variable coefficient of velocity. The maximum coefficient of velocity (20.58) of soybean seed was observed from T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) treatment. The minimum coefficient of velocity 19.45 was found in T_1 (Control) treatment.

4.4.5 Energy of emergence (%)

Energy of emergence showed significant variation due to the different levels of integrated nutrient management (Table 5). The highest energy of emergence 75.73 % was recorded in T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) treatment. The lowest energy of emergence 70.04% was recorded in T_1(Control) treatment.

4.4.6 Shoot length(mm)

Significant variation was observed on shoot length among the different levels of integrated nutrient management (Table 5). The maximum shoot length 155.3 mm was recorded in T_{13} (Biochar 10 t ha^{-}1 + 50% RDF) treatment, which was statistically similar with T_{14} (Biochar 10 t ha^{-}1+ 75% RDF) treatment. The minimum shoot length 144.90 mm was found in T_1 (Control) treatment.

4.4.7 Root length (mm)

Faster cell division in the root tips is the possible reason for longer root length in osmo primed seed than dry seed. Statistically significant variation was recorded in terms of root length of BARI Soybean 5 due to the different levels of integrated nutrient management (Table 5). The maximum root length 58.64 mm was observed from T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) treatment. The minimum root length 52.32 mm was found in T_5 (Trichoderma compost 2 t ha^{-1}) treatment

4.4.8 Vigour index

Vigour index showed highly significant difference at different levels of integrated nutrient management (Table 5). The highest vigour index 148.20 was recorded in

T_{13} (Biochar 10 t ha-1+ 50% RDF) treatment compare to germination index 143.80 was recorded from T_{14} (Biochar 10 t ha^{-1} +75% RDF) treatment. The lowest germination index 117.60 was found in T_1 (Control) treatment

Table 5.Effect of integrated nutrient management on seed quality test of soybean

Treatments	Co-efficient of velocity		Energy of emergence (%)		Root length(mm)		Shoot length(mm)		Vigour index	
T_1	19.45	e	70.04	d	55.22	b-e	144.90	c	117.60	h
T_2	20.00	c	71.81	cd	56.80	abc	150.00	abc	129.10	e
T_3	20.45	b	71.82	cd	55.69	bcd	150.90	ab	122.90	g
T_4	20.08	c	73.41	abc	54.43	c-f	150.30	ab	127.90	e
T_5	19.64	de	73.41	abc	52.32	f	152.00	ab	127.30	ef
T_6	19.41	e	74.99	ab	56.74	abc	153.50	ab	139.80	c
T_7	19.67	de	74.41	abc	53.61	def	150.90	ab	128.90	e
T_8	19.87	cd	72.29	bcd	53.55	def	148.90	bc	124.80	fg
T_9	20.45	b	72.36	bcd	53.45	def	151.30	ab	128.80	e
T_{10}	19.90	cd	73.20	abc	55.37	bcd	150.40	ab	130.50	e
T_{11}	19.68	de	71.97	cd	55.08	b-e	153.60	ab	136.40	d
T_{12}	19.57	e	71.90	cd	52.56	ef	149.80	abc	134.00	d
T_{13}	20.87	a	75.73	a	58.64	a	155.30	a	148.20	a
T_{14}	20.58	b	74.69	abc	57.24	ab	155.10	a	143.80	b
SE value	0.25		2.57		2.40		4.77		3.03	
CV (%)	2.10		2.70		2.60		1.88		5.75	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

4.4.9 Seed viability (%)

According to tetrazolium test, there was statistically significant variation due to different levels of integrated nutrient management in case of seed viability (Fig. 4). The highest seed viabilty (90.00%) was recorded from T_3, T_6, T9, T_{12} and T_{14} the lowest seed viabilty (75.00%) was recorded from T_2 (Cowdung 10 t ha^{-1}).

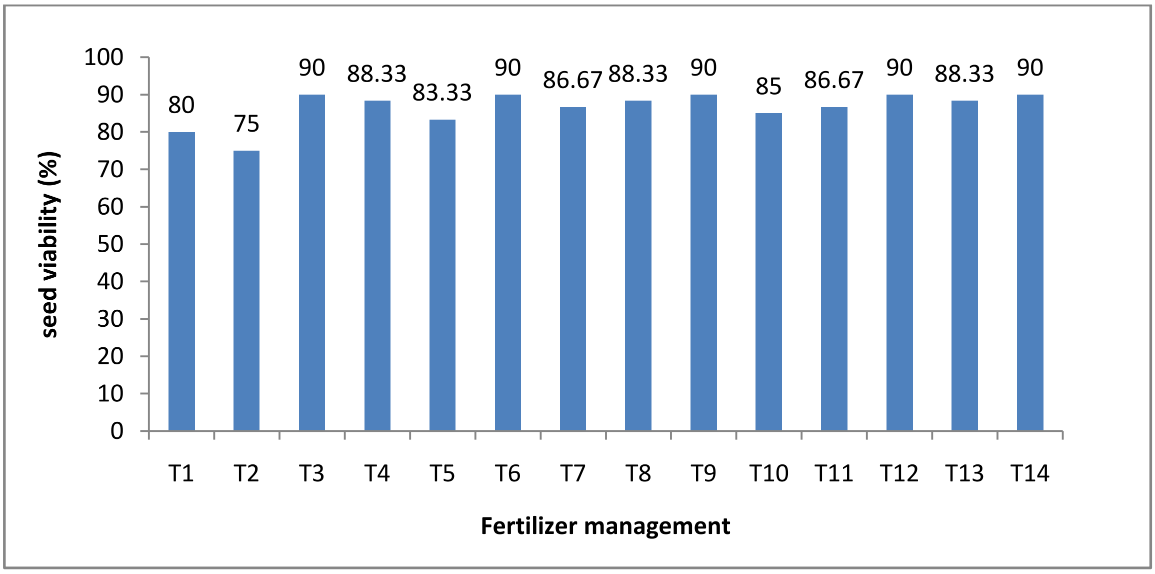

Fig. 4. Effect of different levels of integrated nutrient management on seed Viabilty of soybean (SE=0.02)

T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

CHAPTER IV

SUMMARY AND CONCLUSION

The experiment was conducted during the period from October, 2019 to April 2020 to study the improvement of yield and seed quality of soybean through integrated nutrient management.. In this experiment, the treatment consisted of fourteen different Levels of integrated nutrient management *viz*. T_1= No chemical fertilizer, no organic manure (Control), T_2= Cow dung (10 t ha^{-1}), T_3= Vermi compost (5 t ha^{-1}), T_4= Recommended dose of fertilizer (RDF) (Urea 50 kg ha^{-1} ,TSP 150 kg ha^{-1}, MoP 100 kg ha^{-1}, Gypsum 80 kg ha^{-1} , Boron 8 kg ha^{-1}), T_5= Trichoderma compost (2 t ha^{--1}) , T_6= Biochar (10 t ha^{-1}) T_7= Cowdung (10 t ha^{-1}) + 50% RDF, T_8= Cowdung (10 t ha^{-1})+75% RDF, T_9= Vermi compost (5 t ha^{-1})+ 50%RDF, T_{10}= Vermi compost(5 t ha^{-1}) + 75%RDF, T_{11}= Trichoderma compost(2 t ha^{-1}) + 50% RDF, T_{12}= Trichoderma compost(2 t ha^{-1})+ 75% RDF, T_{13}=Biochar(10 t ha^{-1}) +50% RDF, T_{14}=Biochar (10 t ha^{-1}) +75% RDF

The experiment was laid out in a Randomized Complete Block Design with three replications. The collected data were statistically analyzed for evaluation of the treatment effect.

Plant height of soybean showed statistically significant variation due to different levels of integrated nutrient management at 30, 50, 70 days after sowing (DAS) and at harvest. the tallest plant (37.3, 50.67, 52.53 and 52.93 cm at 30, 50, 70 DAS and at harvest, respectively) was recorded from T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) Number of leaves $plant^{-1}$ of soybean was varied significantly due to different levels of integrated nutrient management.

The maximum number of leaves $plant^{-1}$ (8.87, 29.13, 16.20 cm at 30, 50, 70 DAS, respectively) was attained from T_{13} (Biochar 10 t ha^{-1}+ 50% RDF). Statistically significant variation was recorded due to different levels of integrated nutrient management in terms of pod length of soybean.

The longest pod (3.56 cm) was observed from T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) .Different levels of integrated nutrient management showed statistically significant variation on number of pods $plant^{-1}$. The maximum number of pods $plant^{-1}$ (47.80) was recorded from T_{13} (Biochar 10 t ha^{-1}+ 50% RDF).

Different levels of integrated nutrient management showed statistically significant variation on number of seeds pod^{-1} of soybean. The maximum number of seeds pod^{-1} (3.13) was found from T_{13} (Biochar 10 t ha^{-1}+ 50% RDF).

Weight of 1000 seeds of soybean varied significantly due to different levels of integrated nutrient management under the present study.The highest weight of 1000 seeds (123 g) was observed from T_{13} (Biochar 10 t ha^{-1}+ 50% RDF).

Seed yield of soybean varied significantly due to different levels of integrated nutrient management. The highest seed yield (1333 kg ha^{-1}) was observed from T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) and the lowest seed yield (639 kg ha^{-1}) was observed from T_1 (control) treatment.

Levels of integrated nutrient management exerted significant variation on stover yield of soybean. The maximum stover yield (181 kg ha^{-1}) was observe in T_{14} (Biochar 10 t ha^{-1} +75%RDF).

Different levels of integrated nutrient management significantly varied on biological yield of soybean. However, the highest biological yield (1513 kg ha^{-1}) was found in T_{13} (Biochar 10 t ha^{-1}+ 50% RDF).

Harvest index of soybean showed significant variation for different levels of integrated nutrient management. However the highest harvest index (89.74) was recorded from T_6 (Biochar 10 t ha^{-1}) treatment. The highest total germination 94.33% was obtained in T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) treatment. The longest mean germination time 5.78 days was observed from T_{10} (Vermi compost 1.25 t ha^{-1}+ 75% RDF) treatment. The highest germination index 21.07 was recorded in T_{13} (Biochar 10t ha^{-1}+ 50% RDF) treatment.

The maximum coefficient of velocity (20.58),.highest energy of emergence 75.73 % , maximum shoot length 155.3 mm, maximum root length 58.64 mm, highest vigour index 148.20 was recorded in T_{13} (Biochar 10 t ha^{-1}+ 50% RDF) treatment. The highest seed viability (90.00%) was recorded from T_3, T_6, T9, T_{12} and T_{14}.

From the above results, it may be concluded that Biochar 10 t ha^{-1}+ 50% RDF showed the better performance on most of the growth, yield contributing characters and seed quality characters of soybean. Reduction in germination parameters and seedling growth was more profound in control seeds than other seeds. Considering the yield and sound environment, Biochar 10 t ha^{-1}+ 50% RDF may be possible to use in replacing inorganic fertilizer which will increase seed quality and reduce production cost without significant yield reduction. Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. The results are required to substantiate further with different varieties of soybean.

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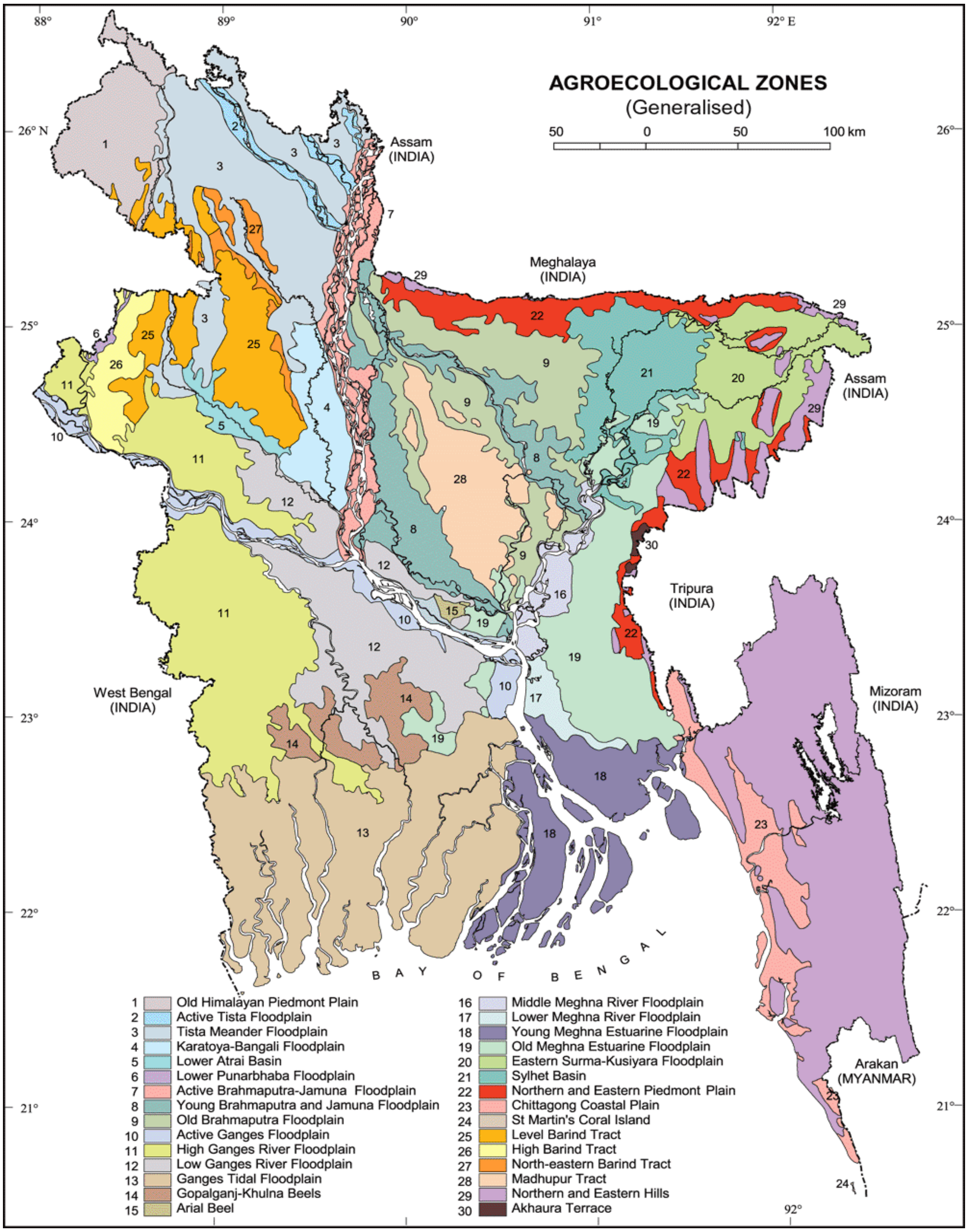
APPENDICES

Appendix I: Experimental location on the map of agro-ecological zones of Bangladesh



Appendix II: **Soil characteristics of experimental farm of Sher-e-Bangla Agricultural University are analyzed by soil Resources Development Institute (SRDI), Farmgate, Dhaka**

A. Morphological characteristics of the experimental field

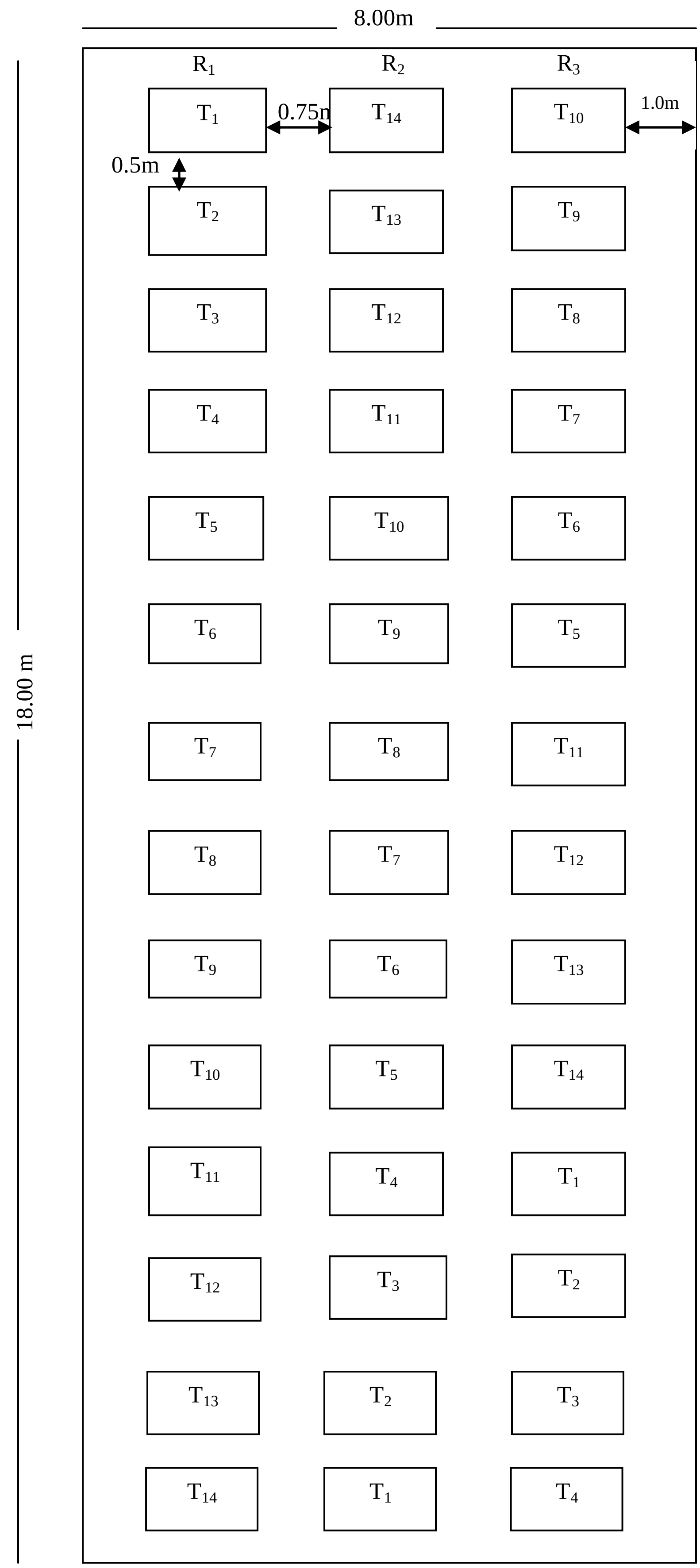
Morphological features	Characteristics
Location	Farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	**N/A**

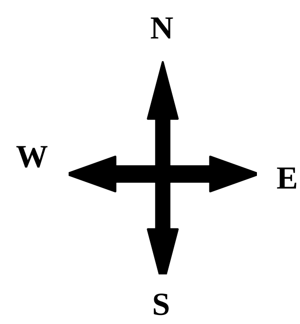
Source: SRDI

B. Physical and chemical properties of the initial soil

Characteristics	Value
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	0.25
Total N (%)	0.02
Available P (µgm/gm soil)	53.64
Available K (me/100g soil)	0.13
Available S (µgm/gm soil)	9.40
Available B (µgm/gm soil)	0.13
Available Zn (µgm/gm soil)	0.94
Available Cu (µgm/gm soil)	1.93
Available Fe (µgm/gm soil)	240.9
Available Mn (µgm/gm soil)	50.6

Appendix III. Layout and design of the experimental plot





Unit plot size:
1 m x 2 m

T_1= No chemical fertilizer, no organic manure (Control)
T_2= cow dung(10 t ha^{-1})
T_3= vermi compost(5 t ha^{-1})
T_4= Recommended dose of fertilizer (RDF)
T_5= Trichoderma compost (2 t ha^{-1})
T_6= Biochar (10 t ha^{-1})
T_7= Cowdung (10 t ha^{-1})+50%RDF
T_8= Cowdung(10 t ha^{-1})+75%RDF
T_9= vermi compost(5 t ha^{-1}) + 50%RDF
T_{10}= vermi compost(5 t ha^{-1}) + 75%RDF
T_{11}= Trichoderma compost(2 t ha^{-1}) + 50%RDF
T_{12}= Trichoderma compost(2 t ha^{-1}) + 75%RDF
T_{13}= Biochar(10 t ha^{-1})+50%RDF
T_{14}= Biochar(10 t ha^{-1}) +75%RDF

Appendix IV. Analysis of variance of the data on plant height of soybean as influenced by levels of integrated nutrient management

Source of variation	Degrees of Freedom	Means square			
		Plant height			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	16.676	4.191	1.715	1.062
Factor A	13	8.696	11.011	9.285	8.884
Error	26	8.434	8.925	8.378	8.532

Appendix V. Analysis of variance of the data on Number of leaves plant^{-1} of soybean as influenced by levels of integrated nutrient management

Source of Variation	Degrees of Freedom	Means square		
		Number of leaves plant^{-1}		
		30 DAS	50 DAS	70 DAS
Replication	2	2.48	34.357	16.723
Factor A	13	0.931	47.879	7.015
Error	26	1.275	41.785	4.331

Appendix VI. Analysis of variance of the data on yield contributing character of soybean as influenced by levels of integrated nutrient management

Source of Variation	Degrees of Freedom	Means square			
		pod length	number of pod plant^{-1}	number of seed plant^{-1}	thousand seed weight
Replication	2	0.25	4.027	0.035	0.25
Factor A	13	0.112	114.383	0.083	0.112
Error	26	0.034	41.333	0.052	0.034

Appendix VII. Analysis of variance of the data on yield of soybean as influenced by levels of integrated nutrient management

		Means square			
Source of variation	Degrees of Freedom	yield	Stover weight	Biological yield	Harvest index
Replication	2	3306.738	299.272	4575.255	1.348
Factor A	13	132944.1	1685.542	154622.9	11.588
Error	26	17435	496.536	18035.02	7.329

Appendix VIII. Analysis of variance of the data on seed quality test of soybean as influenced by levels of integrated nutrient management

		Mean Square								
Sources of Variation	**Degrees of freedom**	Total germination	Mean germination time	germination index	Co-efficient of velocity	Energy of emergence	Root length	Shoot length	Vigour index	Germination percentage
Replication	2	12.819	0.019	0.148	4.03	0.855	42.36	12.819	4.03	11.31
Factor A	13	21.552	0.216	5.453	0.623	7.228	10.393	21.552	0.62	59.57
Error	26	8.075	0.056	0.652	0.023	2.35	2.044	8.075	0.02	18.361