EFFECT OF NPK AND ORGANIC FERTILIZERS ON THE GROWTH AND YIELD OF BLACKGRAM IN OLD HIMALAYAN PIEDMONT PLAIN SOIL (AEZ-1) OF BANGLADESH

A THESIS

BY

DIPIKA BANERJEE

Student No. 1501164

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MASTER OF SCIENCE (M.S.)

IN

SOIL SCIENCE

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HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

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Approved as to style and contents by

.....	.....…….
Prof. Dr. A.K.M Mosharof Hossain	**Prof. Dr. Md. Shahadat Hossain Khan**
Supervisor	Co-supervisor

.....

Prof. Dr. Md. Shahadat Hossain Khan
Chairman
Examination Committee
and
Chairman

DEPARTMENT OF SOIL SCIENCE

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

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DECEMBER, 2023

DEDICATED

TO MY

BELOVED FAMILY

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The Authoress

ABSTRACT

A field experiment was carried out at the Soil Science Research field in Hajee Mohammad Danesh Science and Technology University, Dinajpur during the kharif season of 2022. This study was performed to examine the effects of organic and inorganic fertilizers on the growth and yield of blackgram. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. There were six treatment combinations viz. T_1 = Control (No fertilizer use), T_2 = 100% Recommended Dose (RD) of NPK, T_3 = 100% RD of Cowdung (CD) + Poultry manure (PM) + Vermicompost (VC), T_4 = 75% (CD + PM + VC) + 25% RD of NPK, T_5 = 50% (CD + PM + VC) + 50% RD of NPK, T_6 = 25% (CD + PM + VC) + 75% RD of NPK, respectively. The yield contributing characteristics like plant height, number of leaves plant^{-1}, number of branch plant^{-1}, number of pods plant^{-1}, pod length, thousand seed weight, seed yield ha^{-1} and biological yield ha^{-1} were significantly influenced due to different treatments. In the case of plant height, leaf numbers plant^{-1}, branches plant^{-1}, the highest results were found at different treatments at 15, 30 and 45 DAS but at 60 DAS the highest results were noticed at T_5 treatment. The lowest results were obtained in T_1 treatment. A significant increase in the NPK contents as well as their uptake due to the combined application of organic manures and NPK was observed. The results of soil indicated that the application of NPK fertilizer and organic manure positively influenced the total N, available P, exchangeable K, and available S contents in soils. Therefore, this study reveals that the application of 50% RD of NPK fertilizers along with 50% (CD + PM + VC) might be an efficient practice for achieving economical blackgram production.

ABBREVIATION AND ACRONYMS

%	Percentage
@	At the rate
AEZ	Agro Ecological Zone
BAU	Bangladesh Agricultural University
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
Conc.	Concentration
Contd	Continued
df	Degrees of freedom
DMRT	Duncan's Multiple Range Test
e.g.	Example
et al.	And others
Fig.	Figure
g	Gram
i.e.	That is
IRRI	International Rice Research Institute
J.	Journal
kg	Kilogram
kg^{-1}	Per kilogram
m^{-2}	Per meter square
mg	Milligram
MOC	Mustard oil cake
SOC	Sesame oil cake
FM	Fish meal
No.	Number
^{0}C	Degree Celsius
pH	Potential of H^{+} concentration
ppm	Parts per million
RCBD	Randomized Complete Block Design
RD	Recommended Dose
S	Standard error
t ha^{-1}	Ton(s) per hectare
T	Treatment
viz.	Such as

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Blackgram (*Vigna mungo L.)* is one of the important pulses, grown throughout the Bangladesh. It originated in South Asia, where it has been cultivation since ancient times. It belongs to the Fabaceae family of leguminous crop that improves organic matter content in the soil. On dry weight basis it contains approximately 25–28% protein, 4.5-5.5% ash, 0.5-1.5% oil, 3.5-4.5% fiber and 62.65% carbohydrate (Kaul, 1982). It contains sulphur, amino acids, methionine, cysteine, and balanced human nutrition. The total cultivated land of blackgram in Bangladesh is 74.8 thousand hectares and the production is about 86.8 thousand metric tons (Azad *et al.*, 2020).

Inorganic fertilizer is synthetically comprised of minerals and synthetic chemicals. Various inorganic fertilizers, such as urea, TSP, MoP, etc., are used in agriculture. NPK fertilizer applications significantly increase plant height, stem girth, number of leaves, leaf area, leaf area index, dry matter accumulation and yield of blackgram. The optimum level of NPK 45:80-90:45 fertilizers needed for successful production of blackgram.

Nitrogen (N) is one of the most abundant elements on the earth and plays an important role in modern agriculture (Chen *et al.,* 2018). It also promote flower bud differentiation; enhance fruit setting rate, and increased yield (Raese *et al.*, 2007). It is a component of protein and nucleic acids and when N is suboptimal, growth is reduced (Haque *et al.,* 2001). Its availability in sufficient quantity throughout the growing season is essential for optimum blackgram growth. It is also a characteristic constituent element of proteins and also an integral component of many other compounds essential for plant growth processes including chlorophyll and many enzymes. Optimum amount of these elements in the soil cannot be

utilized efficiently if N is deficient in plants. Therefore, N deficiency or excess can result in reducing blackgram yields.

Phosphorus (P) is an important plant nutrient that is referred to as the master key element in crop production (Pierre, 1938). Consequently, the lack of P is as important as the lack of N limiting blackgram performance. P plays an important part in many physiological processes that occur within a developing and maturing plant. It is associated with several vital functions like seed germination, cell division, flowering, fruiting, and almost every biochemical metabolic activity. It induces root proliferation and nodulation. It also affects the quality of the grains and it may increase the plant resistance to diseases.

Potassium (K) is the most abundant inorganic cation, and it is important for ensuring optimal plant growth (White and Karley, 2010). It is often referred to as the "quality element", because of its contribution to many of the characteristics. K is an activator of dozens of important enzymes, such as protein synthesis, sugar transport, N and C metabolism and photosynthesis. A major limitation for plant growth and crop production under rained condition is soil water availability. Plants that are continuously exposed to drought stress can form reactive oxygen species (ROS), which leads to leaf damage and ultimately decrease crop yield. K plays an important role in the formation of yield and quality improvement (Marschner, 2012).

In recent times, attention has been directed towards organic manure because of the rising cost of inorganic fertilizers, their inability to give the soil, and the desire for sound health. Many types of organic fertilizers are available in Bangladesh, such as cowdung (CD), vermicompost (VC), poultry manure (PM), etc.

Cowdung (CD) contains more plant nutrients than all other organic manures. Owing to its high organic matter content combined with available nutrients needed for improving plant

growth and is widely utilized as an excellent soil amendment. Decomposed CD stimulated microbial activities which contribute to soil fertility restoration.

Vermicompost (VC) is the end-product of the breakdown of organic matter by earthworms. VC contains water soluble nutrients and is an excellent, nutrient rich organic fertilizer. It is used in farming and small scale sustainable organic farming.

Poultry manure (PM), sometimes called chicken manure, is an excellent soil amendment that provides nutrients for growing crops and also improves soil quality when apply wisely. Poultry waste consists of droppings, wasted feed, broker an egg, feathers is used to improve soil health. It is a good source of organic nutrients containing both macro and micro nutrients and its application improves soil carbon content and improve soil physical and chemical properties. In contrast to chemical fertilizer, it adds organic matter to soil which improves soil structures, nutrient retention, aeration, soil water holding capacity and water infiltration (Deksissa *et al.,* 2008). It is also indicated that PM more readily supplies P to plants than other organic manure sources (Garg and Bahla, 2008). Its application registered over 53% increases of N level from 0.09% to 0.014% in the soil and exchangeable cations increases with manure application (Boateng *et al.*, 2006).

Generally, inorganic fertilizers are used for the rapid growth of plants because the nutrients are water soluble. But increased use of inorganic fertilizer is harmful to the environment, soil profile and human health. On the other hand, organic fertilizers are natural in that the nutrients the possesses are comprised of plant or animal based materials. Decomposed CD stimulate microbial activities which contribute to soil fertility restoration. VC increases pore space, reduced bulk density, increased water holding capacity, cation exchange capacity, reduce pH and electrical conductivity, increase carbon content, available N, P, K and microbial population. PM contains substantial amount of Ca, P and protein due to high level of mineral supplement in their diet. From the above discussion it may be said that organic

fertilizers are eco-friendly and good for soil health which are important for our upcoming developing country.

Keeping in view the above review, the present study was undertaken to determine the effect of organic and NPK fertilizers on the growth, yield and yield attributes of blackgram with following specific objectives:

1. To study the combined effect of organic and inorganic fertilizers on the growth and yield of blackgram
2. To suggest a suitable integrated dose of inorganic fertilizers and organic manures for blackgram; and
3. To investigate the effect of organic and inorganic fertilizers on the soil fertility.

CHAPTER II
REVIEW OF LITERATURE

This research has been undertaken to observe the effect of NPK and inorganic fertilizer on the growth and yield of blackgram. Review is a required part of grant of research proposals and often a chapter in thesis. The reviews of literature of the past studies related to the present experiment collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented and discussed in this chapter.

2.1 Effect of organic and inorganic fertilizer on the growth and yield of blackgram

Zaman *et al.* (2018) showed that VC along with different rates of CF exerted significant influence on the growth, leaf biomass yield and sativoside content of stevia and postharvest soil fertility. The highest values for most of the parameters were found from the plant receiving VC @ 7.5 t ha^{-1} along with 50% CF. About 578% higher leaf biomass yield was obtained from the treatment $VC_{7.5}$ + CF_{50} over control. Stevioside content was increased with the increasing levels of VC up to 7.5 t ha^{-1} along with 75% of CF and also with the advancement of growth period from 30 to 60 days after planting. The highest amount of stevioside (11.05%) was detected in the leaves of plant of the same treatment at harvest. Soil acidity was significantly decreased with the increased levels of VC and CF whereas soil fertility in terms of organic matter and nutrient content was increased. Considering the overall performance, farmers may be advised to cultivate stevia in acid soil applying VC @ 7.5 t ha^{-1} along with 50% chemical fertilizer to boost up stevia production under the agro-climatic condition of the study area in the context of Bangladesh.

Bhattacharya *et al.* (2019) showed that VC and urea both has positive effect on seedling growth parameters of *V. mungo* and *V. radiate* [average root length (6.1 cm and 6.7 cm)], shoot length (6.5 cm and 8.3 cm), leaf area (312.2 sq.cm and 334.1 sq.cm] as compared to

control set [average root length (4.4 cm and 4.3 cm)], shoot length (6 cm and 5.9 cm), leaf area (282.7 sq.cm and 305.5 sq.cm). But urea exerts negative effect on seed higher recommended dose of P + K fertilizer. The rate of urea-40 kg ha^{-1}, TSP-70 kg ha^{-1} and MOP-35 kg ha^{-1} and the rate of cow dung and poultry litter were 10 and 5 t ha^{-1} respectively. The results revealed that effect of poultry litter (OM_2) showed its superiority by producing highest yield (1419.5 kg ha^{-1}), which may be attributed to higher blackgram pods $plant^{-1}$ (23.81), seeds pod^{-1} (5.49), seed weight $plant^{-1}$ (3.89 g), weight of 1000 seed (39.83 g) as well as highest pod length (5.11 cm), pod diameter (5.21 cm), plant height (49.68 cm), branches $plant^{-1}$ (7.35) and dry weight plant (36.94 g) in this treatment. On the other hand, 50% higher recommended dose of P+K fertilizer seems promising in blackgram cultivation as this treatment (F_3) gave the highest seed yield (1372.6 kg ha^{-1}) along with highest pod length (5.08 cm), pod diameter (5.19 cm), pods plant (25.15), seeds pod^{-1} (5.44), seed weight $plant^{-1}$ (4.09 g) and 1000 seed weight (39.49 g). Among the interactions, OM_2 F_3 out yielded by producing highest yield (1529.4 kg ha^{-1}) than other interactions. This interactions also produced the tallest plant (53.17 cm), highest number of branches $plant^{-1}$ (7.75) maximum dry weight $plant^{-1}$ (40.51 g), pod length (5.4 cm), pod diameter (5.43 cm), pods $plant^{-1}$ (29.65), seeds pod (4.95 g), 1000 seed weight (44.15 g), seed yield (1529.4 kg ha^{-1}), strover yield (1759.4 kg ha^{-1}), biological yield (3288.8 kg ha^{-1}), harvest index (46.60%), germination percentage (96.83%), seedling length (23.053 cm), seedling dry weight (0.038 g) and lowest EC test value (1621.1 dS cm^{-1}). The study clearly indicated that poultry litter as organic manure and 50% higher recommended doses of P + K fertilizer and their interaction seem promising for producing maximum seed yield and the best quality seed of Blackgram.

Singh *et al.* (2022) carried out an experiment on the use of farmyard manure and bio fertilizer along with application of chemical P was conducted to assess the impact of differential doses of phosphorus, farmyard manure and consortium bio fertilizer application on the

development, yield and P uptake during the year 2018 and 2019. The impact of different treatments was recorded on the plant height, dry matter partition, yield and yield attributes, P uptake and soil P availability using standard methods. The data revealed significant improvement in yield, yield attributes, P uptake and soil P availability. The integration of farmyard manure and bio fertilizer with 60 kg ha^{-1} SSP (single superphosphate) has improved the blackgram yield by 7.4% and 3.28% respectively over the use of 60 SSP alone. The P uptake in blackgram with application of Farm yard manure and bio fertilizer along with 60 kg ha^{-1} SSP has improved the uptake by 7.18% and 2.51% respectively over the use of 60 kg ha^{-1} SSP alone. The results highlight the need of integrated application of farm yard manure, bio fertilizer for sustainable production of blackgram in the region.

Kumawat *et al.* (2015) conducted a field experiment during kharif season of 2008-09 and 2009-10 to study the effect of integrated nutrition on productivity, nutrient uptake and economics of rain fed pigeon pea [*Cajanus cajan* (L.)] and blackgram [*Vigna mungo* (L.)] intercropping system. Pooled data shows that intercropping systems did not influence significantly on the grain, stover, biological yield and harvest index of pigeon pea and blackgram. Total uptake of N, P, K, S and Zn by pigeon pea were highest recorded with the sole pigeon pea (S_1) which was comparable to normal intercropping system (S_2) and significantly superior over paired intercropping system (S_3). Further, pooled data revealed that normal intercropping system (S_2) gave maximum values of gross return (Rs 120050), net return (Rs 99396), B:C ratio (4.8), pigeon pea equivalent yield (21.75 q ha^{-1}), land equivalent ratio (1.70), production efficiency (7.98 kg ha^{-1} day^{-1}) and economic efficiency (364.83 Rs ha^{-1} day^{-1}) which was at par with paired intercropping system (S_3) and significantly superior to sole planting of pigeon pea (S_1). Application of 100% recommended dose of fertilizers + 50% recommended dose of N (through VC) + 5 kg Zn ha^{-1} gave significantly higher grain yield (21.05 and 5.23 q ha^{-1}), stover yield (82.19 and 14.47 q ha^{-1}), biological yield (103.24

and 18.85 q ha^{-1}) and harvest index (20.23 and 26.40%) of pigeon pea and blackgram, respectively. This treatment (F_7) also gave the higher total uptake of N, P, K, S and Zn by pigeon pea and blackgram. Similarly, application of 100% RDF + 50% RDN + 5 kg Zn ha^{-1} (F_7) recorded highest gross return (Rs 130735), net return (Rs 109277), B:C ratio (5.11), PEY (24.24 q ha^{-1}), LER (1.57), production efficiency (8.9 kg ha^{-1} day^{-1}) and economic efficiency (401.07 Rs ha^{-1} day^{-1}) which was at par with 50% RDF + 100% RDN + 5 kg Zn ha^{-1} (F_8) and significantly superior to rest of the treatments.

Jha *et al.* (2015) set up a field experiment at the instructional farm of Rajasthan College of Agriculture, Udaipur, Rajasthan during kharif season of 2013 to study the effect of organic and inorganic sources of nutrients on yield and economics of blackgram. The result indicated that application of 100 % RDF + Zn + Fe (N:P:K- 20:30:15 kg ha^{-1} + $ZnSO_4$ 5 kg ha^{-1} + $FeSO_4$ 5 kg ha^{-1}) recorded significantly highest plant height (34.18 cm), dry matter (10.31 g $plant^{-1}$), leaf area index (2.216), number of pods (32.38 $plant^{-1}$), number of seeds (6.88 pod^{-1}), seed yield (870 kg ha^{-1}), straw yield (1843 kg ha^{-1}), biological yield (2713 kg ha^{-1}), harvest index (32.10%), gross return (Rs 50975), net return (Rs 34930 ha^{-1}) and B:C ratio (3.18), respectively over rest of the treatments but it was at par with 100% RDF, 50% RDF+50% RDN through FYM and FYM 4 t ha^{-1}. The seed yield and net return of blackgram significantly increased by 8.75% and 11.22 %, respectively over 100% RDF. Split dose of VC indicate that split application of VC 1 t ha^{-1} at 30 DAS along with FYM 2 t ha^{-1} (Basal) recorded a significant increase yield and net returns of blackgram over VC 1 t ha^{-1} (Basal)+VC 1 t ha^{-1} at 30 DAS and control, respectively.

Tyagi *et al.* (2019) conducted a field experiment on integrated nutrient management practices for augmenting the productivity of summer blackgram (*Vigna mungo* L.) was carried out in clay loam soil at Research Farm, J.N.K.V.V., College of Agriculture, Tikamgarh (Madhya Pradesh) during summer 2016 and 2017. The experiment was laid out in randomized block

design replicated thrice with ten nutrient management treatments. The results revealed that integration of 100% RDF + VC @ 1.0 t ha^{-1} + *Rhizobium* resulted into significantly greater plant height (52.1 cm), number of primary branches $plant^{-1}$ (5.9), higher total dry biomass accumulation (20.5 g $plant^{-1}$) at harvest, maximum leaf area index (3.11) at 45 DAS, number of pods $plant^{-1}$ (13.3), number of seeds pod^{-1} (10.5), 1000 seed weight (37.9 g) and seed yield (1170 kg ha^{-1}) closely followed by 75% RDF + 1 t VC + *Rhizobium* treatment. The minimum values of these parameters were recorded under 4 t FYM ha^{-1} + *Rhizobium* treatment. Application of 100% RDF + VC @ 1.0 t ha^{-1} + *Rhizobium* also recorded higher N, P and K uptakes by seed (39.6, 4.03 and 9.65 kg ha^{-1} , respectively) and stover (31.3, 4.29 and 10.2 kg ha^{-1}, respectively) as well as total uptakes (70.9, 8.32 and 19.9 kg ha^{-1}, respectively) as compared to rest of treatments. On the other hand, 4 t FYM ha^{-1} + *Rhizobium* resulted in lower values of uptake of nutrients by crop.

Prasad *et al.* (2015) indicated that application of 100 % RDF + Zn + Fe (N:P:K- 20:30:15 kg ha^{-1} + $ZnSO_4$ 5 kg ha^{-1} + $FeSO_4$ 5 kg ha^{-1}) recorded significantly highest plant height (34.18 cm), dry matter (10.31 g $plant^{-1}$), leaf area index (2.216), number of pods (32.38 $plant^{-1}$), number of seeds (6.88 pod^{-1}), seed yield (870 kg ha^{-1}), straw yield (1843 kg ha^{-1}), biological yield (2713 kg ha^{-1}), harvest index (32.10%), gross return (Rs 50975), net return (Rs 34930 ha^{-1}) and B-C ratio (3.18), respectively over rest of the treatments but it was at par with 100% RDF, 50% RDF+50% RDN through FYM and FYM 4 t ha^{-1}. The seed yield and net return of blackgram significantly increased by 8.75% and 11.22 %, respectively over 100% RDF. Split dose of VC indicate that split application of VC 1 t ha^{-1} at 30 DAS along with FYM 2 t ha^{-1} (Basal) recorded a significant increase yield and net returns of blackgram over VC 1 t ha^{-1} (Basal)+VC 1 t ha^{-1} at 30 DAS and control, respectively.

Bhattacharya *et al.* (2019) studied and carried out to evaluate and compare the effects of organic (VC) and inorganic (urea) fertilizers on the germination percentage and seedling

growth of *V. radiata* (Green gram) and *V. mungo* (Blackgram). Fresh weight and dry weight of tested plant samples at 10^{th} days of growth stage were also determined. VC was used as organic fertilizer and urea as inorganic fertilizer. Experimental results showed that VC and urea both has positive effect on seedling growth parameters of *V. mungo* and *V. radiata* [average root length (6.1 cm and 6.7 cm)], shoot length (6.5 cm and 8.3 cm), leaf are (312.2 sq. cm and 334.1 sq. cm] as compared to control set [average root length (4.4 cm and 4.3 cm)], shoot length (6 cm and 5.9 cm), leaf area (282.7 sq. cm and 305.5 sq. cm). But urea exerts negative effect on seed germination percentage in *V. mungo* and *V. radiata* (58% and 50%) as compared to control (77%). VC exhibited better result in above parameters in comparison to urea. *V. mungo* showed increased value in comparison considering *V. radiata* in case of organic, inorganic fertilizer treated as well as control sets. As composition of locally available fertilizers is unknown, the application of these fertilizers for improving germination percentage and growth parameters of tested crop need to be evaluated. Present work may provide the suggestive approach for usage of these tested fertilizers in field level trial.

2.2 Combined effects of organic and inorganic fertilizers on soil properties

Parthasarathi *et al.* (2008) carried out a field experiment during 2002-2003 on clay loam, sandy loam and red loam soil at Sivapuri, Chidambaram, Tamil Nadu, to evaluate the efficacy of VC on the physio-chemical and biological characteristics of the soils and on the yield and nutrient content of blackgram (*Vigna mungo*), in comparison to inorganic fertilizers (N, P, K). VC had increased the pore space, reduced particle and bulk density, increased water holding capacity, cation exchange capacity, reduced pH and electrical conductivity, increased organic carbon content, available N, P, K and microbial population and activity in all the soil types, particularly clay loam. The yield and quality (protein and sugar content in seed) of blackgram was enhanced in soils, particularly clay loam soil. On the contrary, the

application of inorganic fertilizers has resulted in reduced porosity, compaction of soil, reduced carbon and reduced microbial activity.

Umamaheswari *et al.* (2006) studied on blackgram and carried out an analysis of physio chemical properties of VC shows that the pH was uniformly brought to neutral level and insignificant increase of EC was recorded. The chemical analysis of the VC clearly indicated that the compost was rich in N, P, K, essential nutrient for the growth of the plants. Reduction of Organic Carbon and C:N ratio during vermicomposting is the main index to assess the rate of organic matter decomposition. With regard to growth studies of blackgram (*Vigna mungo*) was carried out employed it was observed that the morphological and yield parameters were found to increase significantly (p<0.05) over control.

Moradi *et al.* (2014) claimed that vermicomposts are rich in microbial populations and diversity, particularly fungi, bacteria and actinomycetes. The continued use of chemical fertilizers causes health and environmental hazards such as ground and surface water pollution by nitrate leaching. Compost refers to organic constituents, usually wastes, that have been mixed, piled, and moistened and undergo thermophilic decomposition that alters or decomposes the original organic materials. Many studies have demonstrated the effectiveness of VC in providing protection against various plant diseases.

Haridha *et al.* (2020) conducted a field experiment at Servaikaranmadam of Thoothukudi district, Tamilnadu in kharif season in 2018 on sandy clay loam soil to access the effect of goat manure and VC on the physio-chemical and other properties of the soil. The experiment was laid out in randomized block design (RBD) with three replications. The experiment comprised of ten treatment combinations. The goat manure was relatively high in K, P compared with N. The results of study revealed that application of 17 t ha^{-1} with combination of goat manure and VC showed better pore space as well as water holding capacity and hence the yield of blackgram (V*igna mungo* L.).

Singh (2022) set up a field experiment at agriculture research farm of S.D.J Post Graduate College Chandeshwar, Azamgarh, (U.P.) during 2005-06 and 2006-07. The experiment laid out in Randomized Block Design (RBD) with nine treatment combination viz., three soil treatments in main plot [Control (C_0), Gypsum @ 100 kg ha^{-1} (C_1), FYM @ 5 t ha^{-1} (C_2)] and six chemical fertilizer treatments in sub plot [Blackgram; F_1-100% Recommended ($N_{20}P_{40}K_{20}$), F_2- 75% of recommended ($N_{15}P_{30}K_{15}$), F_3-50% of recommended ($N_{10}P_{20}K_{10}$) and Wheat; F_1-100% Recommended ($N_{120}P_{60}k_{40}$), F_2-75% of Recommended ($N_{90}P_{45}K_{30}$), F_3-50% of recommended ($N_{60}P_{30}K_{20}$)], total number of plots were 36 along with four replications. The result indicates that significantly higher grain yield (pooled 2005-06, 2006-07); Stover yield (2005-06, 2006-07) and biological yield (2005-06, 2006-07) and harvest index (2005-06, 2006-07) were recorded with the application of soil test based FYM @ 5 t ha^{-1} [C_2]and in 100% Recommended ($N_{20}P_{40}K_{20}$) [F_1]. Growth parameters were also found higher with the application of 5 t ha^{-1} FYM and with 100% recommended dose of chemical fertilizer as compare to other treatments. With regards to economics, soil test-based application of 5t FYM ha^{-1} resulted in highest gross returns (Rs. 16591 ha^{-1}), net returns (Rs. 3251 ha^{-1}) and benefit: cost ratio (1.25) over other nutritional treatments. Similarly, in chemical fertilizer treatments the 100% Recommended ($N_{20}P_{40}K_{20}$) obtained the highest gross return (Rs. 16510 ha^{-1}), net return (Rs. 2661 ha^{-1}) and benefit cost ratio (1.27) among the other treatment, respectively.

Mishra *et al.* (2012) carried out an experiment at Phulbani, Odisha to examine the performance of three cropping systems (sole rice, sole blackgram and rice + blackgram) with nine different manure and fertilizer treatments under rain fed upland condition. Different nutrient treatments include Control (Farmers' practice- no nutrient); 100% recommended N through inorganic fertilizer; 50% recommended N through inorganic fertilizer; 25kg N through FYM; 15kg N through FYM + 10kg N through inorganic fertilizer; 15kg N through

FYM + 20kg N through inorganic fertilizer; 15kg N through green leaf + 10kg N through inorganic fertilizer; 15kg N through green leaf + 10kg N through inorganic fertilizer; and 15kg N through FYM + 10kg N through green leaf. Based on the data on mean rice grain equivalent yield (REY) over 12 years from 1998 to 2009, cultivation of sole blackgram was found to be more remunerative (2.43 t ha^{-1} REY) than sole rice (1.42 t ha^{-1}) or rice + blackgram (5:2) (1.28 t ha^{-1}). Considering the three cropping systems together, application of FYM to supply 15 kg N along with chemical fertilizer (urea) to supply 20 kg N + 40 kg P_{2O5} + 40 kg K_2O was found to be the most effective (2.23 t ha^{-1} REY) followed by the same dose of FYM with 10 kg N through fertilizer + 40 kg P_2O_5 + 40 kg K_2O (2.19 t ha^{-1} REY). The best treatment registered 37% higher REY over the recommended fertilizer dose.

Kumar *et al.* (2020) aimed to evaluate the performance of blackgram as influenced by organic and organic source of nutrient under sodic soil condition. The experiment was laid down in randomized block design (RBD) with three replications. Total of 8 treatments encompassing of different organic and inorganic sources of nutrients including control were used in the present investigation to study their individual as well as interaction effect on growth, yield and economics of different lines of blackgram under sodic soil conditions. Supply of the required NPK nutrient was done through Urea, DAP, FYM and VC. The details of treatment specification used in present study are T_0 (control), T_1 (100% RDF), T_2 (100% FYM), T_3 (100% VC), T_4 (50% FYM + 50% VC), T_5 (50% RDF + 50% FYM), T_6 (50% RDF + 50% VC) and T_7 (T7 50% RDF + 25% FYM + 25% VC). Data recorded on growth parameters (plant height, dry weight, number of root nodules, number of branches $plant^{-1}$ and number of flowers $plant^{-1}$), grain yield as well as on economics of blackgram (net return and B:C Ratio) were subjected to different statistical analysis as per method of analysis of variance. Appraisal of the data indicated that treatment-T_6 (50% recommended doses of fertilizers (RDF) + 50% VC) significantly improved the growth parameters viz., plant height

(43.10 cm), dry weight (24.00 gm), number of root nodules (22.36), number of branches plant^{-1} (4.86) and number of flowers plant^{-1} (48.66), Same treatment also recorded significant enhancement in grain yield (7.32 q ha^{-1}) as well as in economics viz., net returns (Rs. 28167) and B:C Ratio (2.09) of blackgram over rest of the treatments under study. Based on present investigation it can be inferred that combined application levels of organic and inorganic fertilizers have positive impact by improving the soil fertility and crop production. From the current study, application of 50% RDF along with 50% VC was found more impressive by improving the growth, yield and economic of blackgram than rest of the treatments including control.

Mahamud *et al.* (2022) studied to observe the effect of combined application of organic manures and inorganic fertilizers on growth, yield and yield contributing characters of blackgram. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The experiment comprises eight treatments viz. Control (no application of manures and fertilizer), Recommended doses of fertilizer (RDF), Cow dung @ 5 t ha^{-1} + 50% of RDF, PM @ 5 t ha^{-1} + 50% of RDF, VC @ 5 t ha^{-1} + 50% of RDF, CD @ 5 t ha^{-1} + PM @ 5 t ha^{-1} + 50% of RDF, Cow dung @ 5 t ha^{-1} + VC @ 5 t ha^{-1} + 50% of RDF and PM @ 5 t ha^{-1} + VC @ 5 t ha^{-1} + 50% of RDF. Combined application of organic manures and inorganic fertilizers exerted significance influence on growth, yield and yield contributing characters of blackgram. At growth, the tallest plant (38.74 cm), the highest number of leaves plant^{-1} (15.55), leaf dry weight plant^{-1} (6.99 g) and stem dry weight plant^{-1} (3.01 g) of blackgram at 50 days after sowing (DAS) were obtained from PM @ 5 t ha^{-1} and VC @ 5 t ha^{-1} along with 50% of RDF. While, at 50 DAS, the highest number of nodules plant^{-1} (55.22) was recorded from cow dung @ 5 t ha^{-1} along with 50% of RDF and the highest number of SPAD value plant^{-1} (42.03) was found in PM @ 5 t ha^{-1} along with 50% of RDF. Again, at maturity, the highest number of seeds pod^{-1} (5.86), yield plant^{-1} (7.77 g),

grain yield m^{-2} (130.70 g) and total dry weight $plant^{-1}$ (17.21 g) were obtained from PM @ 5 t ha1 and VC @ 5 t ha^{-1} along with 50% of RDF. Therefore, it can be concluded that PM @ 5 t ha^{-1} and VC @ 5 t ha^{-1} along with 50% of RD combination might be a promising practice for blackgram cultivation.

Malarvizhi *et al.* (2021) reported that the assessment of organic and inorganic source of nutrients on yield and yield traits of blackgram (*Vigna mungo* L.) cultivar "ADT 6". An investigation was taken up during kharif season of 2019 at SRS Institute of Agriculture and Technology, Vedasandur Taluk, DIndigul district, Tamil Nadu. The experiment was laid down in randomized block design (RBD), consisting of eight treatments which were replicated thrice for comparing the performance of blackgram (*Vigna mungo* L.) cultivar "ADT 6" treated with different levels of organic and inorganic source of nutrients that were applied individually as well as in combination. The results indicates that treatment T_6 that consists of 50%recommended doses of fertilizers (RDF) in combination with 50% VC were far better than rest of treatments under study. It recorded significantly highest number of pods $plant^{-1}$ (49.60), numbers of grains pod^{-1} (5.53), 1000 grain weight (36.76 gm), harvest index (45.39%), grain yield (7.53 q ha^{-1}) and straw yield (13.97 q ha^{-1}) over rest of the treatments.

Sohel *et al.* (2018) conducted an experiment to study the effect of organic and inorganic fertilizers on the growth, yield, and yield components of blackgram in charland area of Chapainawabganj district. The experiment comprised of seven treatments viz. T_1: Control, T_2: 100% RFD (Recommended Fertilizer Dose), T_3: Cow dung (5 t ha^{-1}) + 100% RFD, T_4: Compost (3 t ha^{-1}) + 100% RFD, T_5: VC (3 t ha^{-1}) + 100% RFD, T_6: 1/3 Cow Dung + 1/3 Compost + 1/3 VC + 100% RFD, and T_7: Farmer's practice. The experiment was laid out in a randomized complete block design with three replications. Yield contributing characters of blackgram like number of clusters per plant, days to maturity, number of pods per plant, pod length, number of seeds per pod were significantly influenced by the different treatments.

Results indicated that most yield contributing characters had the maximum values in treatment T_6 (1/3 Cow Dung + 1/3 Compost + 1/3 VC + 100% RFD). The highest grain yield of 13.06 q ha^{-1} was observed in treatment T_6, and the lowest grain yield of 9.56 q ha^{-1} was in T_1 treatment. Application of cow dung, compost, VC, and fertilizer at recommended dose had a significant and positive effect on the growth and yield of blackgram. Among the treatments, the application of cow dung, compost, VC with chemical fertilizers was found to be the most effective practice for blackgram cultivation in charland area of Chapainawabganj district.

CHAPTER III
MATERIALS AND METHODS

An experiment was set up at the soil science field, Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period from 1st March to May 2022 to find out the effect of NPK and organic fertilizer on the growth and yield of blackgram. This chapter presents a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, data collection and analysis of different parameters under the flowing headings.

3.1 Description of the experimental site

3.1.1 Experimental site

The experimental site is situated under the Dinajpur Sadar Upazila and is located at 25.13^0N latitude, 88.23^0E longitude, and at an elevation of 37.5 m above the mean sea level (Appendix-1). The land belongs to the AEZ of Old Himalayan Piedmont Plain, Agro-ecological Zone-1 (AEZ-1). The topography of the field was medium-high.

3.1.2 Climate and weather

The experimental site is situated in the subtropical climatic one, characterized by the heavy rainfall march to July and scanty rainfall during the rest time. At the growing period of crop total rainfall was 65.95 mm. Details of the meteorological data in respect of temperature, rainfall, relative humidity, and total sunshine hours during the growing period of the experimental site are presented in Appendix-II

3.1.3 Soil

The land of the experimental plot was high, leveled, and well-drained and the soil was a non-calcareous brown floodplain. The soil is Ranisankail sandy loam, a member of the Hyperthermic Aeric Haplaquept under the order Inceptisol having only a few horizons,

developed under aquic moisture regime and variable temperature conditions. The general characteristics of the soil are presented in the Table 3.1.

A. Morphological characters

AEZ	Old Himalayan Piedmont Plain
General type of soil	Non-calcareous brown floodplain soil
Parental material	Piedmont alluvium
Drainage	Moderately well drained
Topography	Medium high land
Flood level	Above floodplain

B. Physical characteristics

Sand (%)	53.2
Silt (%)	34
Clay (%)	12.8
Textural class	Sandy loam

C. Chemical characteristics

pH	6.8
Organic matter (%)	0.87
Total N (%)	0.015
Available P (ppm)	42.11
Exchangeable K (meq 100 g^{-1} soil)	0.068
Available S (ppm)	34.48

3.2 Planting Materials

Blackgram seed (Bari Mash 1) was used for the study purpose. Seeds were used in Kharif season. It was collected from Bangladesh Agricultural Research Institute, Gazipur. It was developed by Bangladesh Agricultural Research Institute, Gazipur.

3.3 Experimental Design and Treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The whole area was divided into 3 blocks and each block was divided into 6 units. The total number of treatments was 6 in the present experiment. As each treatment was replicated 3 times, therefore the total number of plots was 18(6×3)

Here,

T_1= 0 (Control).

T_2= RD of NPK

T_3 = 100% RD (CD + PM + VC)

T_4 =75% (CD + PM + VC) + 25% RD of NPK

T_5 = 50% (CD + PM + VC) + 50% RD of NPK

T_6 = 25% (CD + PM + VC) + 75% RD of NPK

Here

RD = Recommended dose

NPK = Nitrogen, phosphorus and potassium

CD = Cowdung

PM = Poultry manure

VC = Vermicompost

Note: According to Bangladesh Agricultural Research Institute (BARI) the recommended dose of Urea, TSP and MOP fertilizers 40-45 kg ha^{-1}, 80-90 kg ha^{-1} and 40-45 kg ha^{-1} respectively

3.4 Layout of the experimental plots

Total number of plots	: 18
Individual plot size	: 1 m^2 (1 m × 1 m)
Space between block to block	: 0.5 m
Space between plot to plot	: 0.25 m
Treatment	: 6
Replication	: 3

The layout of the experimental field is shown in the figure.1

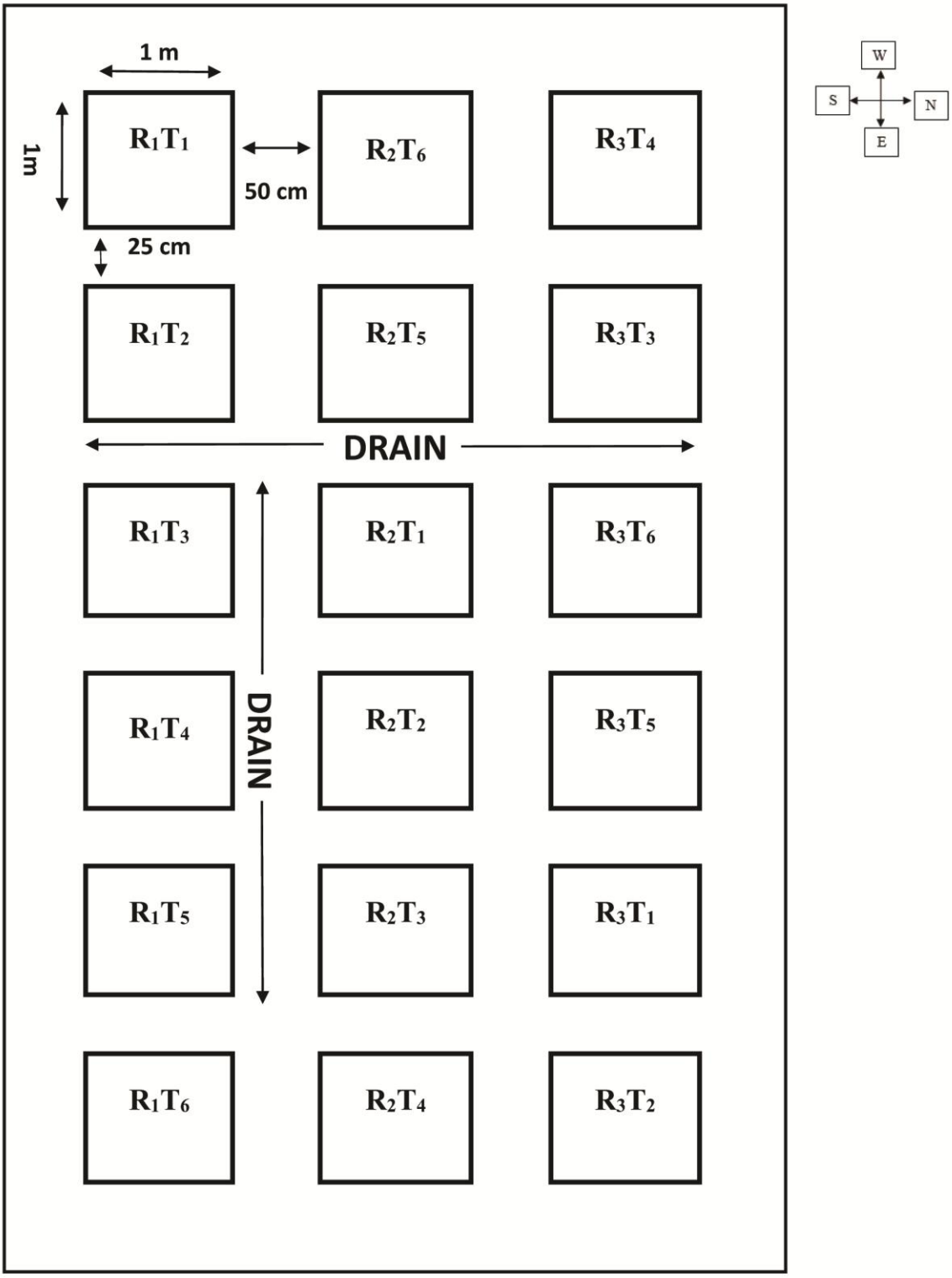

Figure: A layout of the experimental field

3.5 Land preparation

The land was prepared on 1st March 2022 by plowing and cross plowing with a power tiller. Every ploughing was followed by laddering to have a good tilth. Weeds and stubbles of the previous crop were collected and removed from the experimental plot before final ploughing, puddling and leveling.

3.6 Fertilizer and Manure application

Here, N, P and K fertilizers were used as urea, TSP and MP. The percentage of NPK fertilizers and manures were applied as per recommended doses which was urea 45 kg ha^{-1}, TSP 85 kg ha^{-1}, MP 45 kg ha^{-1} (Fertilizer Recommended Guide, 2018), CD 5 t ha^{-1}, PM 2.6 t ha^{-1} and VC 2.5 t ha^{-1}. Total amount of NPK fertilizers and organic fertilizers were applied before final land preparation.

3.7 Seed sowing

Blackgram seed (BARI MASH-3) was used for the study purpose. BARI MASH-3 seeds were sowing in the at Kharif-I (March to May) season. It was collected from Bangladesh Agricultural Research Institute (BARI), Dhaka. Plant spacing was maintained with five row and seed to seed spacing was maintained 10 cm and row to row distance was maintained 25 cm.

3.8 Intercultural operations

Intensive care was taken during the growing period to ensure adequate growth and development of the crop, which are given below:

3.8.1 Weeding

Three-hand weeding was done at 15, 30 and 45 days after seed sowing.

3.8.2 Irrigation

The plots were irrigated from deep tube-well as needed during the growing period of the crop.

3.8.3 Insect and pest control

Foliar spray was done for leaf mosaic of blackgram MoP 4g/5L, Urea 8.75g/5L and Sulphur 10g/5L were applied. Other inorganics Autostin 50 WDG, Knowin 50 WP, Siconazol 5 SC, were applied for pesticide and fungicide.

3.9 Harvesting

Blackgram plants were harvested when full maturity came. The crops were harvested plot wise and brought to a clean threshing floor of farm house. The yield of the grain and straw per plot were recorded after threshing and drying.

3.10 Data collection

Three plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the following parameters were recorded from the sample plants during the experiment.

3.11 Data recorded at harvest

The following parameters were recorded at harvest:

- Plant height
- Number of leaves plant^{-1}
- Number of branches plant^{-1}
- Number of pod plant^{-1}
- Pod length
- Shoot dry weight plot^{-1}
- Grain yield plot^{-1}
- Thousand seeds weight

- Biological yield
- N in plant (%) (root + shoot + pod)
- Protein in plant (%) (root + shoot + pod)

3.11.1 Plant height

The plant height was measured in centimeters from the base of the plant to the terminal growth point of the main stem on tagged plants were recorded at 15 days intervals starting at 15, 30, 45 and 60 days after transplanting to observe the growth rate of plants. The average height was computed and expressed in centimeters.

3.11.2 Number of leaf plant^{-1}

Five plants were taken at random from each plot and the total numbers of leaves plant^{-1} were calculated.

3.11.3 Number of branches plant^{-1}

The number of branches per plant was counted after sowing from plants. The average of three plants was computed and expressed in the average number of branches per plant.

3.11.4. Number of pods plant^{-1}

Five plants from each plot were selected randomly from each replication. At maturity, pods were harvested in different pickings. Pods of five selected plants were calculated and means were recorded.

3.11.5. Pod length

Pod length was calculated from ten pod of five plants and means were calculated.

3.11.6. Shoot dry weight

Shoot dry weight was calculated after oven drying manually after harvesting from the five tagged plants and total dry weight was calculated.

3.11.7 Grain yield plot^{-1}

Five plants from each plot were selected randomly from each replication. At maturity, pods were harvested in different pickings. Pods of five selected plants were calculated and means were recorded.

3.11.8 Biological Yield

Biological yield was calculated by using the following formula.

Biological yield = Seed yield + Straw yield

3.12 Analysis of soil sample

Initial and Post-harvest Soil samples for chemical properties were analyzed in the laboratory of the Department of Soil Science, HSTU, Dinajpur. The following analysis of the soil sample was done -

- Soil pH
- Organic matter content
- Total N %
- Available P
- Exchangeable K
- Available S

3.12.1 Collection and preparation of soil sample

3.12.1.1 Initial soil sample

The initial soil sample was collected from the plow depth layer (0-15 cm). Ten samples were taken by an auger from 10 locations covering the whole experimental plot and mixed thoroughly to make a composite sample. The composite sample was air-dried, grounded, sieved, and stored in a plastic bag for physical and chemical analyses.

3.12.1.2 Post-harvest soil sample

After harvesting the crop 5 soil samples were collected from each plot at 0 - 15 cm depth. The soil samples were air-dried, grounded, and sieved. Prepared soil samples were stored in plastic.

3.12.2 Particle size analysis

Particle size analysis was done by the hydrometer method (Boyoucus, 1926) and the textural class was determined by plotting the results for % sand, % silt, and % clay in the Marshall's triangular coordinating following the USDA system.

3.12.3 Soil pH

Soil pH was determined by using a glass electrode pH meter using 1:2.5 soil: water ratio. The suspension was allowed to stand for one hour after occasional shaking before determination (Jackson, 1967).

3.12.4 Organic matter content

Soil organic carbon content was determined volumetrically by wet oxidation method using $K_2Cr_2O_7$ and H_2SO_4 mixture and $FeSO_4$ solution was used for titration as outlined by (Jackson, 1967). The organic matter content was calculated by multiplying the percent organic carbon with the Lean Bemmelen factor of 1.724 (Piper, 1950).

3.12.5 Determination of total N from soil samples

One gram (1g) of oven-dry ground soil samples was taken in a micro-Kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se 100: 10: 1), 3 ml 30% H_2O_2, and 5 ml H_2SO_4 were taken into the flasks. The flasks were rotated and allowed to stand for about 10 minutes. Then it was heated at 360-420°C and continued until the digest was clear and colorless. The contents were taken into 100 ml volumetric flasks after cooling and the volumes were made

up to the mark with distilled water. A reagent blank was prepared in the same way. These digests were used for N determination. 40% NaOH was added with the digests for distillation after the completion of digestion. The evolved ammonia was trapped in 4% Boric acid solution and 5 drops of the mixed indicator of bromocressol green and methyl red solution. At last, the distillates were titrated with the standard 0.01 N H_2SO_4 until the color changed from green to pink (Bremner and Mulvaney, 1982)

3.12.6 Available P

Available phosphorous (P) was extracted from the soil with 0.5 M sodium bicarbonate solution at pH 8.5 (Olsen *et al.*, 1954). P in the extract was then determined by developing blue color with $SnCl_2$ reduction of phosphomolybdate complex and the color intensity was measured calorimetrically at 660 nm wavelengths (Page *et al.*, 1982).

3.12.7. Exchangeable K

Exchangeable K was determined from the ammonium acetate extraction method using flame photometer as described by Page *et al*. (1989).

3.12.8 Available S

Available S was determined by extracting the soil sample with 0.01 M $Ca(H_2PO_4)_2$. The sulphur content in the extract was estimated turbid metrically and the intensity of turbid was measured by spectrophotometer at 420 nm wavelength.

3.13 Statistical analysis

The data were analyzed statistically (Gomez and Gomez, 1984) by F-test to examine whether the treatment effects were significant. The mean comparisons of the treatment were evaluated by DMRT (Duncan's Multiple Range Test). The analysis of variance (ANOVA) for different treatment parameters was done by a computer package program "SPSS".

CHAPTER IV
RESULTS AND DISCUSSION

An experiment was conducted to determine the effect of NPK and organic fertilizer on the growth and yield of blackgram. The data have been depicted in various tables and figures. Results are discussed and possible explanations have been given under the following sub heads:

4.1 Effect of NPK and organic fertilizer on the yield and yield components of blackgram

4.1.1 Plant height

The application of different rate of NPK and organic (CD+PM+VC) fertilizers showed a positive effect on the plant height of blackgram (Table 4.1). The application of NPK and organic fertilizer increased the plant height of blackgram. There were no-significant different (p> 0.05) among the treatments at different days after sowing (DAS) of blackgram except 60 DAS. The plant height increased progressively with increasing days after sowing. At 15 DAS, the highest plant height (9.83 cm) was observed in treatment T_5 and the lowest plant height (8.27 cm) was recorded in treatment T_1. Again at 30 DAT, the longest plant (26.60 cm) was observed from the treatment T_2 and the shortest plant height (23.87 cm) was found in T_1. At 45 DAS, the highest plant height (47.70 cm) was observed in treatment T_2, and the lowest plant height (43.33 cm) was recorded in treatment T_1. At 60 DAS all the treatments were significantly different (p< 0.05) and treatment T_5 gave the tallest plant (55.67 cm) which was statistically similar to T_2 (53.20 cm), T_3 (48.33 cm), T_4 (51.00 cm) and T_6 (50.73 cm), while the shortest plant (45.33 cm) was obtained in plots that were T_1 treatment where no fertilizer was applied. At 60 DAS, the treatments with respect to plant height were ranked in the order of T_5>T_2>T_4>T_6>T_3> T_1.

Table 4.1: Effect of NPK and organic fertilizers on the plant height of blackgram at DAS

Treatments	Plant height (cm)			
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**
T_1	8.27	23.87	43.33	45.33 b
T_2	9.25	26.60	47.70	53.20 ab
T_3	9.19	23.93	46.40	48.33 ab
T_4	9.58	25.27	46.13	51.00 ab
T_5	9.83	24.60	47.53	55.67 a
T_6	9.44	23.93	46.00	50.73 ab
Significant level	NS	NS	NS	*
$LSD_{0.05}$	1.98	3.44	5.14	8.10
CV	7.78	5.08	4.06	5.82

In the figures having a similar letter (s) do not differ significantly at 5% level of significance. * = 5% level of significance; ** = 1% level of significance; NS = Not significance; LSD=Least Significant Difference

Treatment combinations were as follows

T_1: Control

T_2: 100% RD of NPK

T_3: 100% RD (CD + PM + VC)

T_4: 75% (CD + PM + VC) + 25% RD of NPK

T_5: 50% (CD + PM + VC) + 50% RD of NPK

T_6: 25% (CD + PM + VC) + 75% RD of NPK

Here,

RD = Recommended dose

NPK = Nitrogen, phosphorus, potassium

CD = Cowdung

PM = Poultry manure

VC = Vermicompost

Application of NPK and organic fertilizer might have improved the soil's physical properties, particularly soil porosity, structure, and water holding capacity, and supplied other plant growth promoting nutrients and substances. As a result, the increasing dose of NPK and organic fertilizer rates significantly increased plant height. The result of the present study was similar to the findings of Prasad *et al.* (2015) and Anasuyamma *et al.* (2022) who observed that the application of VC with inorganic fertilizer showed the best performance for plant height.

4.1.2 Number of leaves plant^{-1}

The number of leaves plant^{-1} is an important yield-determining factor of blackgram. The number of leaves plant^{-1} was significantly different ($p< 0.05$) among the studied different treatments at different DAS except 15 DAS. The number of leaves plant^{-1} was influenced by the application of different rates of NPK and organic fertilizers (Table 4.2). At 15 DAS, the maximum number of leaves plant^{-1} (5.00) was found in treatment T_5 and the lowest number of leaves plant^{-1} (4.50) was found in treatment T_1. At 30 DAS the maximum number of leaves plant^{-1} (14.3) was found in treatment T_4 which was significantly similar to T_2 (13.93), T_3 (13.33), T_1 (12.93), and T_5 (12.80) and the lowest number of leaves plant^{-1} (11.67) was found in treatment T_6. At 45 DAS the maximum number of leaves plant^{-1} (24.33) was found in treatment T_5 where 50% (CD + PM + VC) + 50% RD of NPK were applied and which was significantly parallel with T_2 (22.20), T_3 (20.47), T_4 (20.93), and T_6 (22.60) and the lowest number of leaves plant^{-1} (19.00) was found in treatment T_1. At 60 DAS the maximum number of leaves plant^{-1} (37.00) was found in treatment T_5 where 50% (CD + PM + VC) + 50% RD of NPK ware applied. The treatment was T_5 significantly similar to T_2 (33.20), T_3 (32.46), T_4 (32.73), and T_6 (34.60) and the lowest.

Table 4.2: Effect of NPK and organic fertilizer on the number of leaves plant^{-1} of blackgram at DAS

Treatments	Number of leaves plant^{-1}			
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**
T_1	4.50	12.93 ab	19.00 c	31.00 b
T_2	4.86	13.93 a	22.20 a-c	33.20 ab
T_3	4.77	13.33 ab	20.47 bc	32.46 ab
T_4	4.83	14.3 a	20.93 a-c	32.73 ab
T_5	5.00	12.80 ab	24.33 a	37.00 a
T_6	4.87	11.67 b	22.60 ab	34.60 ab
Significant Level	NS	*	*	*
$LSD_{0.05}$	0.75	2.03	3.41	5.47
CV	5.66	5.62	5.75	5.95

In the figures having a similar letter (s) do not differ significantly at 5% level of significance. * = 5% level of significance; ** = 1% level of significance; NS = Not significance; LSD=Least Significant Difference

Treatment combinations were as follows

T_1: Control
T_2: 100% RD of NPK
T_3: 100% RD (CD + PM + VC)
T_4: 75% (CD + PM + VC) + 25% RD of NPK
T_5: 50% (CD + PM + VC) + 50% RD of NPK
T_6: 25% (CD + PM + VC) + 75% RD of NPK

Here,

RD = Recommended dose
NPK = Nitrogen, phosphorus, potassium
CD = Cowdung
PM = Poultry manure
VC = Vermicompost

number of leaves plant^{-1} (31.00) was found in treatment T_1. The treatments which showed the highest number of leaves plant^{-1} were probably due to more nutrient availability. The result of the present study was similar to the findings of Bhattacharya *et al.* (2019) who found that the application of VC with inorganic fertilizer showed the best performance for the number of leaves plant^{-1}.

4.1.3 Number of branches plant^{-1}

The number of breaches plant^{-1} is an important yield contributing factor of blackgram but no significant differences were observed among the treatments at different DAS. The number of breaches plant^{-1} was influenced by the application of different rates of NPK and organic fertilizer (Table 4.3). At 30 DAS, the maximum number of breaches plant^{-1} (4.20) was found in the treatment T_2 which was higher than the other treatments and the lowest number of breaches plant^{-1} (3.67) was found in the treatment T_1. At 45 DAS, the maximum number of breaches plant^{-1} (4.60) was found in the treatment T_6 but the lowest number of breaches plant^{-1} (4.00) was observed in the treatment T_1. At 60 DAS, the maximum number of breaches plant^{-1} (6.80) was found in the treatment T_5 and the lowest number of breaches plant^{-1} (5.63) was observed in the treatment T_1. The number of breaches increased due to different doses of NPK and organic fertilizer applications. The treatments those showed the highest number of breaches plant^{-1} were due to more nutrient availability by NPK and organic fertilizer application throughout the growing season. The result of the present study was similar to the findings of Prasad *et al.* (2015) who reported that the application of VC and inorganic fertilizer showed a significant effect on number of branch plant^{-1}.

Table 4.3: Effect of NPK and organic fertilizers on the number of branches plant^{-1} of blackgram at DAS

Treatments	Number of branches plant^{-1}		
	30 DAS	**45 DAS**	**60 DAS**
T_1	3.67	4:00	5.63
T_2	4.20	4.53	6.03
T_3	3.87	4.13	6:00
T_4	3.87	4.30	6.17
T_5	3.97	4.53	6.80
T_6	3.97	4.60	6.33
Significant Level	NS	NS	NS
$LSD_{0.05}$	0.73	0.66	1.27
CV	6.8	5.55	7.48

In the figures having a similar letter (s) do not differ significantly at 5% level of significance.

* = 5% level of significance; ** = 1% level of significance; NS = Not significance; LSD=Least Significant Difference

Treatment combinations were as follows

T_1: Control

T_2: 100% RD of NPK

T_3: 100% RD (CD + PM + VC)

T_4: 75% (CD + PM + VC) + 25% RD of NPK

T_5: 50% (CD + PM + VC) + 50% RD of NPK

T_6: 25% (CD + PM + VC) + 75% RD of NPK

Here,

RD = Recommended dose

NPK = Nitrogen, phosphorus, potassium

CD = Cowdung

PM = Poultry manure

VC = Vermicompost

4.1.4 Number of pods plant^{-1}

A significant variation ($p< 0.05$) was observed on the number of pods plant^{-1} due to application of NPK and organic fertilizers (Table 4.4). The number of pods plant^{-1} of different treatments varied from 36.97 to 61.60. The number of pods plant^{-1} (61.60) was highest at T_2 treatment when 100% RD of NPK was applied and the lowest number of pods plant^{-1} (36.97) was recorded in treatment T_4. The result shows the application of NPK with organic fertilizer had positive effect on the number of pod plant^{-1}. This result was in agreement with Bhattacharya *et al.* (2019).

4.1.5 Pod length

The pod length was influenced by the application of NPK and organic fertilizers (Table 4.4). The maximum length of pod (4.48 cm) was found in treatment T_5 and the lowest length of the pod (4.07 cm) was recorded in treatment T_1. The result of the present study was similar to the findings of Tyagi *et al.* (2019) who found that additional use of organic and inorganic fertilizer increased the lateral pod emergence and improved cell permeability.

Table 4.4: Effect of NPK and organic fertilizer on the number of pods plant^{-1} and pod length of blackgram

Treatments	Number of pod plant^{-1}	Pod length (cm)
T_1	40.03 c	4.07
T_2	61.60 a	4.36
T_3	48.73 b	4.27
T_4	36.97 c	4.30
T_5	56.47 a	4.48
T_6	40.93 c	4.31
Significant Level	*	NS
$LSD_{0.05}$	6.68	0.47
CV	5.13	3.99

In the figures having a similar letter (s) do not differ significantly at 5% level of significance. * = 5% level of significance; ** = 1% level of significance; NS = Not significance; LSD=Least Significant Difference

Treatment combinations were as follows

T_1: Control
T_2: 100% RD of NPK
T_3: 100% RD (CD + PM + VC)
T_4: 75% (CD + PM + VC) + 25% RD of NPK
T_5: 50% (CD + PM + VC) + 50% RD of NPK
T_6: 25% (CD + PM + VC) + 75% RD of NPK

Here,

RD = Recommended dose
NPK = Nitrogen, phosphorus, potassium
CD = Cowdung
PM = Poultry manure
VC = Vermicompost

4.1.6 Thousand seed weight

No significant variation ($p > 0.05$) in thousand seed weight was recorded due to incorporation of NPK and organic fertilizers (Table 4.6). The maximum weight of thousand seeds (43.62g) was found in treatment T_5 and the lowest weight (40.73 g) was found in treatment T_1.

4.1.7 Grain yield

A significant variation ($p < 0.05$) in grain yield plot^{-1} was recorded due to incorporation of NPK and organic fertilizers (Table 4.6). It was found that the maximum grain yield (0.85 t ha^{-1}) was found in treatment T_5 which was statistically similar to T_2 (0.82 t ha^{-1}) and the lowest grain yield (0.53 t ha^{-1}) was recorded in treatment T_1. Grain yield in t ha^{-1} increased due to different doses of NPK and organic fertilizer applications. The treatment T_5 showed the highest grain yield due to more nutrient availability by NPK and organic fertilizer application throughout the growing season. Prasad *et al.* (2015) evaluated that the effect of organic fertilizer on grain yield t ha^{-1} of blackgram.

4.1.8 Biological yield

Application of NPK with different amounts of organic fertilizers showed a significant variation ($p < 0.05$) for biological yield of blackgram. A perusal of table 4.5 showed that maximum biological yield (7.49 t ha^{-1}) was obtained in T_5 treatment which was statistically similar to T_2 (7.15 t ha^{-1}) and T_6 (7.00 t ha^{-1}) treatments. The lowest biological yield (5.90 t ha^{-1}) was recorded from plot where no NPK and organic fertilizers were applied (control). These results are in line with those of Jha *et al.* (2015).

Table 4.5: Effect of different doses of NPK and organic fertilizers on the thousand seed weight, grain yield and biological yield of blackgram

Treatments	1000 seed weight (g)	Grain Yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)
T_1	40.73	0.53 d	5.90 c
T_2	41.83	0.82 a	7.15 a
T_3	40.75	0.67 c	6.34 c
T_4	40.90	0.68 c	6.49 bc
T_5	43.62	0.85 a	7.49 a
T_6	41.58	0.76 b	7.00 ab
Significant Level	NS	*	*
$LSD_{0.05}$	4.968	0.077	0.638
CV	4.36	1.95	3.39

In the figures having a similar letter (s) do not differ significantly at 5% level of significance. * = 5% level of significance; ** = 1% level of significance; NS = Not significance; LSD=Least Significant Difference

Treatment combinations were as follows

T_1: Control

T_2: 100% RD of NPK

T_3: 100% RD (CD + PM + VC)

T_4: 75% (CD + PM + VC) + 25% RD of NPK

T_5: 50% (CD + PM + VC) + 50% RD of NPK

T_6: 25% (CD + PM + VC) + 75% RD of NPK

Here,

RD = Recommended dose

NPK = Nitrogen, phosphorus, potassium

CD = Cowdung

PM = Poultry manure

VC = Vermicompost

4.2 Nitrogen (N) content in plant

The N content in plant was significantly ($p < 0.05$) influenced by the application of different doses of NPK with organic fertilizers (Table 4.6) ranging from 2.46 to 3.02%. The highest N content (3.02%) in plant was observed in the treatment T_5 due to application of 50% RFD of NPK + 50% (CD + PM + VC). The lowest N content in plant (2.46%) was noted in the treatment T_1 (control). Increased rate of NPK showed better performance in producing top amount of shoot N over other treatments. The interaction effect of NPK and organic fertilizer application probably increased shoot N through supplying macro nutrient (NPK) that are important for N content in shoot. Kumawat *et al.* (2015) experienced that application of VC and inorganic fertilizer showed significant effect on N concentration in blackgram shoot.

4.3 Chemical properties of the collected soil at harvesting

4.3.1 Total N

The total N content in the post-harvest soil varied significantly ($p< 0.05$) by different treatments. The total soil N of the post-harvest soil was higher than the initial soil (Table 4.7). The total N content of the post-harvest soil ranged between 0.014 and 0.031%. The highest N (0.031%) was found in treatment T_5 where 50% RD of NPK + 50% (CD + PM + VC) were applied. The lowest N (0.014%) was found in the T_1 treatment. The results indicated that the application of NPK and organic fertilizer exerted an increasing trend on total N content of post-harvest soil. This result was in agreement with Kumar *et al.* (2020) who found that application of VC with inorganic fertilizer showed significant influence on total N in soil.

Table 4.6: Effect of NPK and organic fertilizer on N and protein contents in shoot of blackgram

Treatments	Total N in plant (%) (root + shoot + pod)	Protein in plant (%) (root + shoot + pod)
T_1	2.46 c	15.38 c
T_2	2.64 b	16.48 b
T_3	2.51 c	15.69 c
T_4	2.47 c	15.44 c
T_5	3.02 a	18.88 a
T_6	2.49 c	15.56 c
Significant Level	*	*
$LSD_{0.05}$	0.119	0.742
CV	1.67	1.67

In the figures having a similar letter (s) do not differ significantly at 5% level of significance. * = 5% level of significance; ** = 1% level of significance; NS = Not significance; LSD=Least Significant Difference

Treatment combinations were as follows

T_1: Control
T_2: 100% RD of NPK
T_3: 100% RD (CD + PM + VC)
T_4: 75% (CD + PM + VC) + 25% RD of NPK
T_5: 50% (CD + PM + VC) + 50% RD of NPK
T_6: 25% (CD + PM + VC) + 75% RD of NPK

Here,

RD = Recommended dose
NPK = Nitrogen, phosphorus, potassium
CD = Cowdung
PM = Poultry manure
VC = Vermicompost

4.3.2 Available P

The available P content of the post-harvest soil varied significantly ($p < 0.05$) by different treatments of NPK and organic fertilizer application. Available P content varied from 41.71 ppm to 70.00 ppm (Table 4.7). The maximum (70.00 ppm) P content was observed in treatment T_2 where 100% RD of NPK were applied and which was statistically similar to T_6 (65.627 ppm). The lowest P content (41.71 ppm) was observed in the T_1 treatment (control). The release of P from P containing fertilizer and the decomposition of organic fertilizer might be the cause of increasing trend of available P in soils. This result was in agreement with Mishra *et al.* (2012).

4.3.3 Exchangeable K

There were no significant differences in the exchangeable K contents in post-harvest soil ($p > 0.05$). The exchangeable K content of the initial soil was 0.068 (meq 100 g^{-1} soil) and the values of post-harvest soil ranged between 0.064 to 0.120 (meq 100 g^{-1} soil). The highest value of exchangeable K (0.120 meq 100 g^{-1} soil) was found in the treatment T_2. The lowest value of exchangeable K (0.064 meq 100 g^{-1} soil) was found in T_1 treatment (Table 4.7). This result was in agreement with Sohel *et al.* (2018) who experienced that VC and inorganic fertilizer application showed positive effect on exchangeable K in soil.

4.3.4 Available S

The amount of available S in the post-harvest soil was different for the different treatments. The available S content in the studied soil ranged from 28.89 ppm to 38.71 ppm (Table 4.7). The highest S content (38.71 ppm) soil was found in the treatment T_2 where 100% RD of NPK were applied. The lowest S content (28.89 ppm) was observed in treatment T_4. The result showed significantly different ($p < 0.05$) among the different treatments of the post-harvest soil. Sohel *et al.* (2018) and Kumar *et al.* (2020) showed similar result that VC and inorganic fertilizer application showed positive effect on available S in soil.

Table 4.7: Effect of different doses of NPK and organic fertilizer on the total N, available P, exchangeable K, and available S on the post-harvest soil

Treatments	Total N (%)	Available P (ppm)	Exchangeable K (meq $100g^{-1}$ soil)	Available S (ppm)
T_1	0.014 c	41.71 e	0.064	32.43 bc
T_2	0.029 a	70.00 a	0.120	38.71 a
T_3	0.017 bc	47.64 d	0.096	34.42 b
T_4	0.021 b	54.19 c	0.098	28.89 c
T_5	0.031 a	59.30 b	0.069	33.41 b
T_6	0.030 a	65.63 a	0.101	32.41 bc
Initial soil	0.015	42.12	0.068	34.48
Significant Level	*	*	NS	*
$LSD_{0.05}$	0.004	4.54	0.057	3.75
CV	7.52	2.94	22.89	4.10

In the figures having a similar letter (s) do not differ significantly at 5% level of significance.
* = 5% level of significance; ** = 1% level of significance; NS = Not significance; LSD=Least Significant Difference

Treatment combinations were as follows

T_1: Control
T_2: 100% RD of NPK
T_3: 100% RD (CD + PM + VC)
T_4: 75% (CD + PM + VC) + 25% RD of NPK
T_5: 50% (CD + PM + VC) + 50% RD of NPK
T_6: 25% (CD + PM + VC) + 75% RD of NPK

Here,

RD = Recommended dose
NPK = Nitrogen, phosphorus, potassium
CD = Cowdung
PM = Poultry manure
VC = Vermicompost

4.4 Correlation and regression studies

Grain yield of blackgram is a complex character, which results from interactions of many characters. Grain yield was positively correlated with plant height, number of pods plant^{-1}. The correlation matrix and regression lines of these parameters are shown in below:

4.4.1 Correlation between Grain yield and plant height

The positive and significant correlation co-efficient is presented in figure 4.1(a), 4.1(b), 4.1(c) and 4.1(d). At 15 DAS the relationship between plant height and grain yield has been found out. The correlation co-efficient value of the plant height and grain yield was (R^2 = 0.6921) found significant at 5% level of probability. The line of regression X (plant height) on Y (Grain yield) having Y= 0.1804x- 0.9542 was shown in the figure 4.1(a).

At 30 DAS the relationship between plant height and grain yield showed positive and significant correlation co-efficient that presented in figure 4.1(b). The correlation coefficient value of the plant height and grain yield was (R^2=0.2473) found significant at 5% level of probability. The line of regression X (plant height) on Y (Grain yield) having Y= 0.0537x – 0.6107 was shown in the figure 4.1(b).

At 45 DAS the relationship between plant height and grain yield showed positive and significant correlation co-efficient that presented in figure 4.1(c). The correlation coefficient value of the plant height and grain yield was (R^2 = 0.8661) found significant at 5% level of probability. The line of regression X (plant height) on Y (Grain yield) having Y = 0.0691x – 2.473 was shown in the figure 4.1(c).

The relationship between plant height and grain yield at 60 DAS showed positive and significant correlation figure 4.1(d). The correlation co-efficient value was R^2 = 0.9047. The line of regression X (Plant height) on Y (Grain yield) having Y= 0.0306x – 0.837revealed that the grain

yield depends on the character of plant height, because the positive slope indicates that the grain yield and plant height was directly correlated as well as increasing in the plant height increased the grain yield of blackgram.

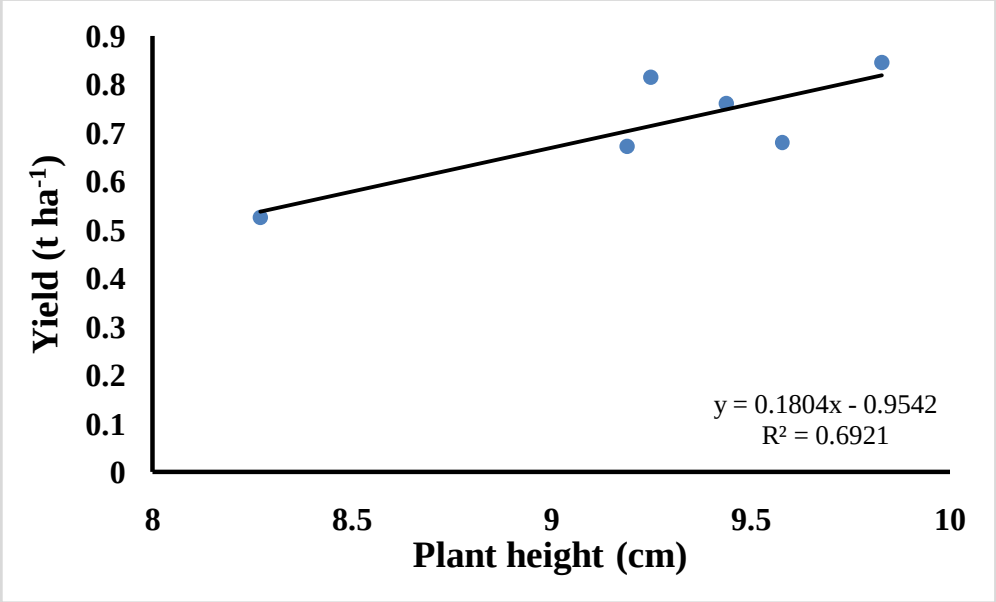

Fig. 4.1 (a) Co-relationship between plant height and grain yield (t ha^{-1}) at 15 DAS

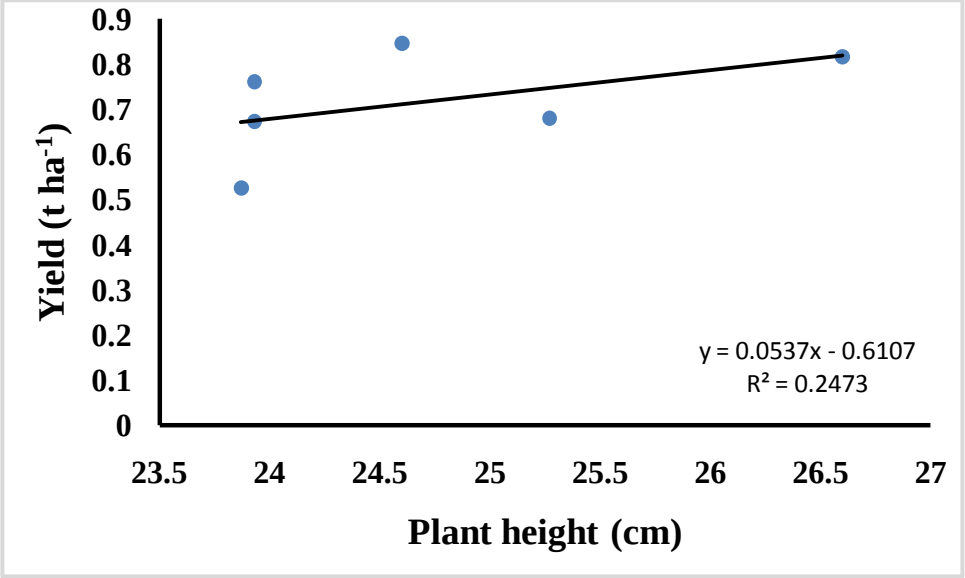

Fig. 4.1 (b) Co-relationship between plant height and grain yield (t ha^{-1}) at 30 DAS

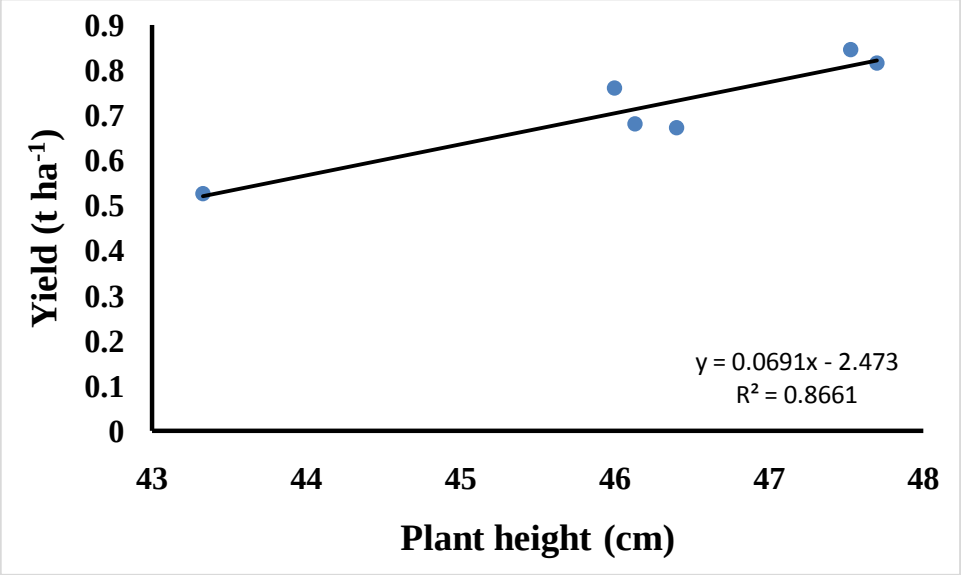

Fig. 4.1 (c) Co-relationship between plant height and grain yield (t ha^{-1}) at 45 DAS

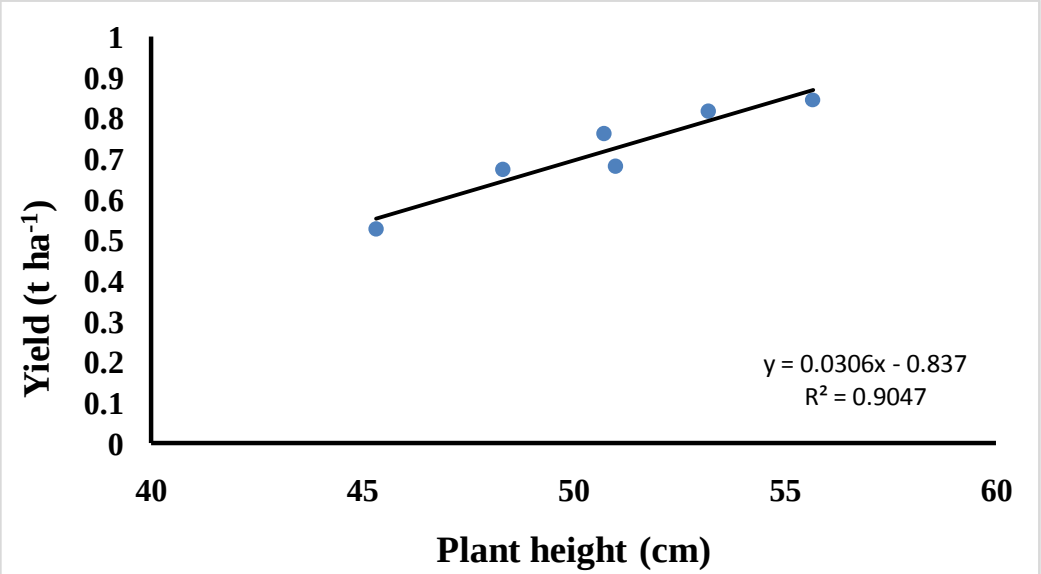

Fig. 4.1 (d) Co-relationship between plant height and grain yield (t ha^{-1}) at 60 DAS

4.4.2 Correlation between grain yield and number of pods plant^{-1}

The relationship between the grain yield and number of pods plant^{-1} has been found out. The positive and significant correlation was presented in the fig. 4.2. The correlation co-efficient value of the grain yield and number of pods plant^{-1} was (R^2 = 0.4833) found significant at 5% level of probability. The line of regression X (Number of pods plant^{-1}) on Y (Grain yield) having Y = 0.0082x+ 0.3283 was shown in the fig. 4.2. The positive slope indicates that the grain yield and number of pods plant^{-1} is correlated with each other thus, due to the increase of the number of pods plant^{-1} grain yield also increased.

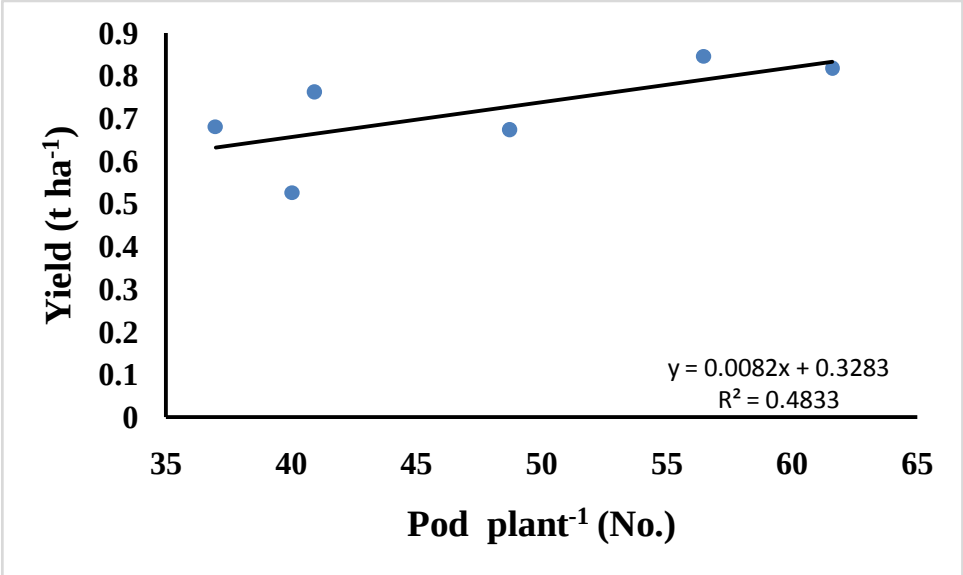

Fig. 4.2 Co-relationship between grain yield and number of pods plant^{-1}

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1 Summary

The study was conducted at the Soil Science research field in Hajee Mohammad Danesh Science and Technology University, Dinajpur during the kharif season of 2022 (March-May) to study the effect of organic and inorganic fertilizers on the growth and yield of blackgram. The soil belongs to the AEZ of the Old Himalayan Piedmont Plain. The soil was sandy loam having pH 6.8, organic matter content 0.87 %, total N 0.015 %, available P 42.116 ppm, exchangeable K 0.068 meq 100 g^{-1} soil, and available S 34.48 ppm. There were six treatment combinations comprising each plant along with a control. The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The total number of plots was 18. Different doses of organic and inorganic fertilizer were used as treatment viz. T_1 = Control (No fertilizer use), T_2 = 100% RD of NPK, T_3 = 100 % (CD + PM + VC), T_4= 75 % (CD + PM + VC) + 25% RD of NPK, T_5 = 50% (CD + PM + VC) + 50% RD of NPK, T_6 = 25% (CD + PM + VC) + 75% RD of NPK were applied before seed sowing. The seed sowing was done on 6th March 2022. Optimum intercultural operations were done as the research was necessary. The plant was harvested on 29th May 2022, at the maturity stage. Data was collected at 15 DAS interval from each of plot to analyze yield and yield contributing characters viz. plant height, number of leaves plant^{-1}, number of branch plant^{-1}, number of pods plant^{-1}, pod length, shoot fresh weight plot^{-1}, shoot dry weight plot^{-1}, seed weight plot^{-1}, biological yield plot^{-1}. The post-harvest soil samples were also analyzed to determine the total N, available P, exchangeable K, and available S contents. The data was statistically analyzed by using statistix 10 to test the coefficient of variation (CV) and the level of significance (LSD) at 0.05%.

The study revealed that all the yield-contributing characters for blackgram viz. plant height, leaf number, number of branches, pod number, pod length, thousand seeds weight, biological yield, grain yield were significantly influenced by different treatments used in the experiment. The tallest values of plant height at 15, 30, 45 and 60 DAS were found 9.83 cm, 26.60 cm, 47.70 cm and 55.67 cm at T_5, T_2, T_2 and T_5 treatments, respectively. The highest values of leaf number plant^{-1} at 15, 30, 45 and 60 DAS were found 5.00, 14.30, 24.33 and 37.00 at T_5, T_2, T_5 and T_5 treatments, respectively. The highest values of branches plant^{-1} at 30, 45 and 60 DAS were found 4.20 cm, 4.60 cm and 6.80 cm at T_2, T_6 and T_5 treatments, respectively. The highest values were found in number of pod plant^{-1} (61.60) at T_2, pod length (4.48 cm) at T_5, thousand seed weight (43.62 g) at T_5 grain yield (0.85 t ha^{-1}) at T_5 biological yield (7.49 t ha^{-1}) at T_5 treatment. The shortest values of plant height at 15, 30, 45 and 60 DAS were found 8.27 cm, 23.87 cm, 43.33 cm and 45.33 cm at T_1 treatment. The lowest values of leaf number plant^{-1} at 15, 30, 45 and 60 DAS were found 4.50, 11.67, 19.00 and 31.00 at T_1, T_5, T_1 and T_1 treatments respectively. The lowest values of branches plant^{-1} at 30, 45 and 60 DAS were found 3.67 cm, 4.00 cm and 5.63 cm at T_1 treatment. The lowest values were found in number of pod plant^{-1} (36.97) at T_4, pod length (4.07 cm) at T_1, thousand seed weight (40.73 g) at T_1 grain yield (0.53 t ha^{-1}) at T_1 biological yield (5.90 t ha^{-1}) at T_1 treatment.

Application of organic manure and NPK fertilizers resulted in a considerable influenced on the properties of the post-harvest soils such as total N, available P, exchangeable K and available S. In post-harvest soil application of organic manure and inorganic fertilizers gave positive result. The total highest levels of N (0.031 %) was found in T_5 {50% (CD + PM + VC) + 50% RD of NPK} treatment whenever P, K and S (70.00 ppm, 0.12 meq. 100g soil^{-1} and 38.71 ppm, respectively) were found in T_2 {100% RD of NPK} treatment and lowest

levels of N, P, K and S (0.014%, 41.710 ppm, 0.064 meq. 100g $soil^{-1}$ and 32.43 ppm, respectively) were in T_1 treatment where no fertilizer was applied.

From the study, it was found that blackgram responded better to the nutrients supplied by the application of organic manures and NPK fertilizers. The utilization of combined organic manure and NPK fertilizer resulted from statistically parallel effects in producing better yield and improved soil properties. Here, 50% (CD + PM + VC) + 50% RD of NPK gives better performance in respect of yield parameters than the other combinations. The application of 50% (CD + PM + VC) + 50% RD of NPK performed better in increasing the soil properties compared to other treatments. So, blackgram can be cultivated in AEZ-1 soil profitably be combined application of organic manure with NPK fertilizer that will provide better yield and also improve soil properties.

5.2 Conclusions

From the results of the study, it may be concluded that:

- Application of 50% (CD + PM + VC) with 50% RD of NPK fertilizers significantly influenced the growth and yield of black gram.
- The application of 50% (CD + PM + VC) with 50% RD of NPK fertilizers significantly increased the amount of total N, available P, exchangeable K, and available S in the soil to some extent.
- Application of different concentrated inorganic and organic fertilizers significantly improves soil health, improving crop yield, and ensure environmental sustainability.
- Organic fertilizers have demonstrated their potential to enhance the overall productivity of blackgram while minimizing the negative environmental impact of excessive chemical fertilizer use.

5.3 Recommendation

- Considering the above observation farmers can be recommended to apply 50% (CD + PM + VC) + 50% RD of NPK fertilizers to obtain maximum yield of blackgram.
- Further study is also needed to enhance soil fertility status by combined application of concentrated organic fertilizer and NPK fertilizer to ensure better growth and yield of blackgram in other regional areas of Bangladesh.

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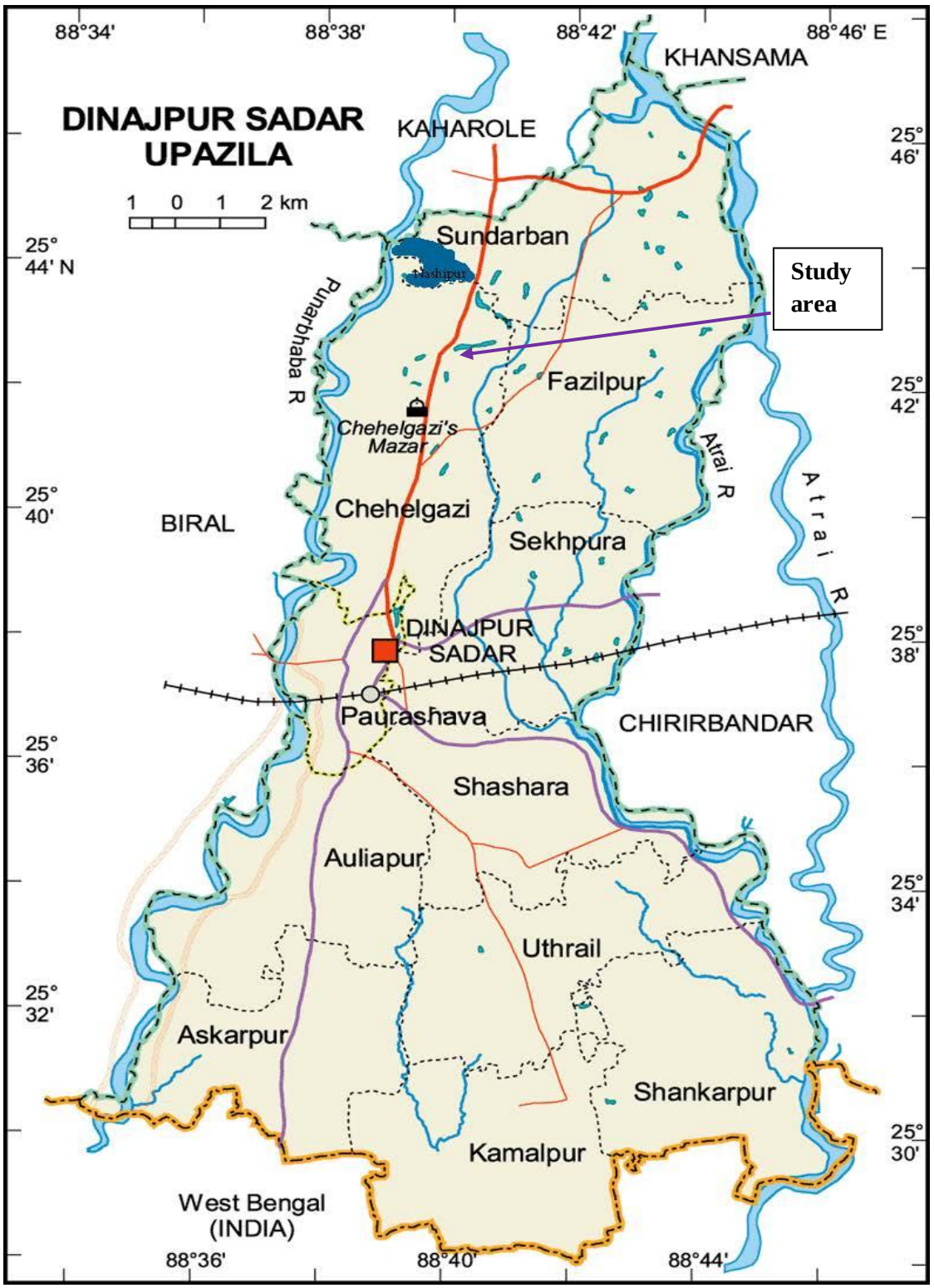
APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research plot)



Appendix II. Monthly recorded air temperature, relative humidity, and rainfall during the research period (From March to July 2022)

Year	Month	**Temperature (^{0}C)		**Relative Humidity (%)	**Rainfall (mm)
		Minimum	Maximum		
2022	March	16.9	31.1	63	11.3
	April	20.8	33.3	68	67.1
	May	23.0	32.6	76	232.5
	June	25.5	32.7	82	335.3
	July	25.5	32.8	84	433.6

**Monthly average

Source: Bangladesh Meteorological Department.

Appendix III. Some photographs of experimental site


R1 T3


R1 T1
R2 T3
R3 T6