EFFECT OF NANOPRODUCT AND CARBENDAZIM ON GROWTH, YIELD AND YIELD COMPONENTS OF BORO RICE

SAIDUN NESA SWARANI

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER, 2021

EFFECT OF NANOPRODUCT AND CARBENDAZIM ON GROWTH, YIELD AND YIELD COMPONENTS OF BORO RICE

A THESIS

BY

SAIDUN NESA SWARANI

REGISTRATION NO.: 19-10210

E-mail: ssaidunnesa569@gmail.com

Mobile: 01743732006

A Thesis

Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

AGRONOMY

SEMESTER: July-December, 2021

Approved by:

____
(Prof. Dr. H. M. M. Tariq Hossain)
Supervisor

____
(Prof. Dr. Md. Hasanuzzaman)
Co-supervisor

____
(Prof. Dr. Md. Abdullahil Baque)
Chairman
Examination committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that the thesis entitled “**EFFECT OF NANOPRODUCT AND CARBENDAZIM ON GROWTH, YIELD AND YIELD COMPONENTS OF BORO RICE”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY,** embodies the results of a piece of bona-fide research work carried out by **SAIDUN NESA SWARANI,** Registration No. **19-10210** under my supervision and guidance. No part of this thesis has been submitted to 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.

Dated:

Dhaka, Bangladesh

(Prof. Dr. H.M.M. Tariq Hossain)

Supervisor

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENT

Alhamdulillah, all praises are due to the almighty **Allah Rabbul Al-Amin** for His kindness and infinite mercy in all the endeavors of the author to let her successfully completed the research work and the thesis for pursuing Master of Science degree.

The author would like to express heartfelt gratitude and most sincere appreciations to her Supervisor **Prof. Dr. H. M. M. Tariq Hossain,** Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his valuable guidance, advice, immense help, encouragement, and support throughout the study. Likewise, grateful appreciation is conveyed to Co-Supervisor **Dr. Md. Hasanuzzaman,** Associate Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for constant encouragement, cordial suggestions, constructive criticism, and valuable advice to complete the thesis.

The author expresses her deepest respect and boundless gratitude to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic cooperation, and inspiration throughout the course of this study and research work.

The author wishes to extend her special thanks to Jawad, Turan and Arwa, for their help during experimentation. Special thanks to all my other friends for their support and encouragement to complete this study.

The author is deeply indebted to her parents, brothers, sisters, and other relatives for their moral support, encouragement and love with cordial understanding.

Finally, the author appreciates the assistance rendered by the staff members of the Department of Agronomy, Sher-e-Bangla Agricultural University Farm, Dhaka, who have helped her during of the study.

The Author

EFFECT OF NANOPRODUCT AND CARBENDAZIM ON GROWTH, YIELD AND YIELD COMPONENTS OF BORO RICE

Abstract

An experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka during the period of December, 2019 to May, 2020 with a view to study on the effect of Stalwart Nano Product (SNP2) and a commercial fungicide (Carbendazim) on growth, yield and yield components of Boro rice. The experiment was carried out in a Randomized Complete Block Design (RCBD) with three replications. Two rice varieties (BRRI dhan28 and BRRI dhan63) and the Nanoproduct with or without Carbendazim [07 levels of which were denoted by T_0 – controlled (only water); T_1 – Carbendazim @ 2g L^{-1}; T_2 –SNP2 @ 1.0 ml L^{-1}; T_3 – SNP2 @ 2.0 ml L^{-1}; T_4 –SNP2 @ 3.0 ml L^{-1}; T_5 – Carbendazim @ 2g L^{-1}+ SNP2 @ 1.0 ml L^{-1} and T_6 – Carbendazim @ 2g L^{-1}+ SNP2 @ 2.0 ml L^{-1}] were considered as factors of the experiment. Analysis of variances were done through CROPSTAT software and significant levels of treatments were judged at 5% level of probability. The mean separation test was done by LSD at 5% level of significance. Matrix ranking, and scoring were done for placing performances of treatments in order by relating to the scores to the weight given to different data obtained from parameters studied. Results revealed that BRRI dhan63 showed higher result than BRRI dhan28 in respect of grain yield (6.11 t ha^{-1}) as evidenced by the highest dry matter accumulation (g) and lower unfilled grains $panicle^{-1}$. As an individual effect of the Nanoproduct, the highest grain yield (5.74 t ha^{-1}) was shown by T_5 due to reflection of the highest no. of total tillers $hill^{-1}$, effective tiller $hill^{-1}$ and filled grains $panicle^{-1}$. However, in the case of combined effect of treatments, the uppermost level of grain yield (6.35 t ha^{-1}) was recorded in BRRI dhan63 treated with T_5 treatment. In this case the best result was facilitated due not only to the highest effective tillers per hill with filled grains per panicle but also the lowest number of non-effective tiller and unfilled grains per panicle recorded in our study. Result also revealed that the use of the Nanoproduct boosted up yield comparing to the control treatment (T_0) in both varieties under study.

LIST OF CONTENTS

LIST OF CONTENTS (CONT'D)

LIST OF CONTENTS (CONT'D)

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	=	AGRO-Ecological Zone
Ag NPs	=	Silver Nano product
Agric.	=	*Agriculture*
Agril.	=	*Agricultural*
Analyt.	=	*Analytics*
App.	=	*Applied*
AWD	=	Alternate Wetting and Drying
Biosci.	=	*Bioscience*
Biochem.	=	*Biochemistry*
Bioinf.	=	*Bioinformatics*
Biopest.	=	*Biopesticides*
BBS	=	Bangladesh Bureau of Statistics
BFS	=	Bulk Foliar Spray
BRRI	=	Bangladesh Rice Research Institute
CuO NPs	=	Copper Oxide Nano Products
Chem	=	*Chemistry*
CV	=	Co-efficient of variance
DAS	=	Days after sowing
DAT	=	Days after transplanting
Div.	=	*Division*
df	=	Degrees of freedom
EMS	=	Error mean square
Ecotoxicol.	=	*Ecotoxicology*
Env.	=	*Environmental*
F_{cal}	=	Calculated value of f
$F_{tabulated}$	=	Tabulated value of f
GM	=	Grand mean
GMO	=	Genetically Modified Organism
GT	=	Grand Total
HI	=	Harvest Index
Int.	=	*International*
J.	=	*Journal*

MC	=	Moisture Content
MS	=	Mean Square
Mg	=	Magnesium
MgO	=	Magnesium Oxide
MgO NPs	=	Magnesium Oxide Nano product
MBC	=	Maximum Bacterial Concentration
Nutr.	=	*Nutrition*
NFS	=	Nano Foliar Spray
nAgO	=	Silver Oxide Nano product
nCuO	=	Nano form of Copper Oxide
nMgO	=	Nano form of Magnesium Oxide
nZnO	=	Nano form of Zinc Oxide
LSD	=	Least significant test
Pollut.	=	*Pollution*
Phytochem.	=	*Phytochemistry*
Pharmacog.	=	*Pharmacognosy*
Phytopath.	=	*Phytopathology*
Physiol.	=	*Physiology*
Pl.	=	*Plant*
RCBD	=	Randomized Complete Block Design
Res.	=	*Research*
ROS	=	Reactive Oxygen System
Sci.	=	*Science*
Stud.	=	*Studies*
SS	=	Sum of Square
SDG	=	Sustainable Development Goal
Techn.	=	*Technology*
USDA	=	United States Department of Agriculture
Univ.	=	*University*
SNP2	=	Stalwart Nano Product 2
ZnO NPs	=	Zinc Oxide Nano Product

CHAPTER I

INTRODUCTION

Bangladesh is an agro-based country. Most of the economic activities mainly depend on Agriculture. About 40.6% people of our country are directly involved in the Agricultural sector (Bangladesh economic review, 2022-2023); the Geographic and agronomic conditions of Bangladesh are favorable for rice production. “Rice security” is synonymous with “Food security”. Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996). For maintaining food security, rice cultivation in proper ways and management is highly needed. There are mainly three rice-growing seasons in our country. They are- Aus, Aman and Boro seasons. Boro is a rabi crop, short-durated variety and irrigated. Boro alone captured 53.75% of total production (Agriculture Statistics Wing, BBS, 2022). So maximum demand for rice grain is fulfilled by Boro rice. Bangladesh is the 3rd largest global rice producing country, recently surpassing Indonesia after a bumper harvest of Boro rice (USDA Monthly Report, 2020). All data indicate that socio-economic contribution of Boro rice is highly noticeable. Therefore, it is important to cultivate it in such condition so that the growth, yield and yield components can be enhanced.

A particle of matter that is between 1 & 100 nanometers (nm) in size is called nanoparticles or ultra-fine particle. A science of manipulating materials at nano scale is called nanotechnology. It occupies a central position among all latest technological achievements. We can apply it in every stage of production to consumption of agricultural products. It can reduce the use of synthetic herbicide, pesticide and fertilizers with increased efficiency. Dream of automated, now it becomes reality to centrally controlled Agriculture by using nano-technology. Conventional farming will not able to feed the huge population without depleting environment. Nevertheless, use of nano-materials not only feeds the world but also prevents the environment from depletion. Bala et al., (2019), evaluated the efficacy of ZnO NPs as Remedial Zinc (Zn) nano fertilizer of rice. The microbial counts and the dehydrogenase activity were also improved by foliar application of nZnO. The study confirmed the potential of foliar application of Zinc micronutrient nano fertilizer for remediation of the Zn- deficiency symptoms in rice CV.PR-121. Global food production, food security and food safety has managed potentially by nanotechnology. The applications of nano materials in the “Nano” form into agriculture practices can enhance the efficiency and sustainability of agricultural practices by requiring less input and more output without hampering environment. All over the world, nanotechnology is being utilized for crop improvement. It must be the solution of increasing yield potential by keeping natural resources safe. On the other hand, excess use of synthetic products has shown the negative impacts on soil, crops and environment. Residual effects destroy the soil ecosystem, it decreases soil fertility and productivity, sometime creates toxicity into food products including grains. Applications of nano materials can alter the present scenario of a global food scarcity and can address the negative effects of excessive use of agro-chemicals who cause bio-magnification in the ecosystem (Baker et al., 2017). Stalwart Nano Product 2 (SNP2) is one kind of formulation which is consisted of copper (Cu), Zinc (Zn) and Magnesium (Mg). The three elements are important plant micronutrients for plant growth and development. Mg captures sun energy in the form of photon that enhances to produce Chlorophyll.

Therefore, photosynthesis also increases getting more chlorophyll. When photosynthesis rate increases more than respiration rate, ultimately production increases what we desire. Zinc (Zn) is used for increasing yield and growth of food crops. Copper (Cu) is an essential micronutrient which incorporated into different enzymes and protein and plays a significant role in plant body. It has antifungal and antibacterial properties in "Nano" form where in "Bulk" form it may be toxic in nature. Cu nanoparticles are synthesized from plant extract and microorganisms, which has a great impact on crop and pathogenic microorganisms. Biologically synthesized Cu nanoparticles show wonderful antibacterial and antifungal activity (Kasana et al, 2016). Because of the combination of micro-nutrients, it provides better yield, eco-friendly at lower cost but high efficiency, safe to use, non-toxic, possible mixing with other pesticides, high quality crops with no cosmetic residues, odorless and hydrophilic in nature. For maintaining food security for next generation, SNP2 or Carbendazim or their combination is applied on Boro rice combining with other agronomic practices; we can achieve our goal economically. The main problem of rice production is the potential yield cannot be achieved through the maximum use of all agronomic practices in practical field rice cultivation. There have some differences in potential yield and practical yield; through using nanoproduct or Carbendazim or their mixed solution, growth and yield can be increased and the difference between potential yield and practical yield can be reduced. ZnO (25 nm particle size) at 1000 ppm concentration proved to be effective in increasing stem and root and root growth in peanuts (Sabir et al., 2014). Adhikari et al., (2012) found maximum growth was found at 100 ppm for soybean and 60 ppm for chickpea seedlings through using of nCuO. It was shown Zinc nano product (nZnO) (25 nm) @ 1000 ppm concentration promoted pod yield per plant was 34% higher compared to chelated bulk $ZnSO_4$ (Prasad et al., 2012); Results was indicated that Fe and Zn chelate nano @ 2 (per 1000) concentration significantly influenced on yield of cucumber. (Javadimoghadam et al., 2015); Poornima & Rv, (2019) found the effects of nZnO on sorghum yield and grain Zn content. Grain yield was 9.5% higher in 500 ppm of Nano foliar spray as compare with 1000 ppm of Bulk foliar spray. (Ramadan et al., 2020) found some positive changes by using FeO and MgO NPs as nano fertilizers on soybean plant. Mathivanan & Prabavathy, (2007) got the result that carbendazim + mancozeb at 2.0 g L^{-1} gave the highest seed yield comparing with control. Yadav et al., (2013) found Carbendazim as maximum reduction of spot blotch incidence, severity and gave highest yield comparing with micronutrients and only water of wheat. That means Carbendazim as a phytohormone beside fungicide has a positive effect of yield enhancement.

However, we fixed up the following objectives to conduct our research work as follows:

I. To study the effect of nanoproduct and Carbendazim on the growth and yield of Boro rice.

II. To evaluate the varietal performances of Boro rice sprayed with different levels of nanoproduct and Carbendazim.

CHAPTER II

REVIEW OF LITERATURE

Growth, yield and yield parameters of rice considerably depend on manipulation of basic ingredients of agriculture. The basic ingredients include variety, environment and agronomic practices. Use of different types of chemicals through agronomic practices is more responsible for increasing growth, yield and yield components parameters than control treatment in practical rice yield. From some literature review, we can see maximum positive effects as well as negative effects by applying micronutrients as a Nano product compared with bulk particles or other chemicals and Carbendazim. The nano products not only increase the growth, yield and yield parameter but also provides sustainability and Carbendazim is basically used as fungicide but it has growth and yield promoting ability also. Now-a-days, sustainable agriculture is needed for protecting our natural resources. The development of nano chemicals has appeared as promising agents for the plant growth, fertilizers and pesticides. In recent years, the use of nano materials has been considered as an alternative solution to control plant pests including insects, fungi and weeds too. The available relevant reviews of related application of nano particles in the recent past have been presented and discussed under the following heading:

2.1 Effects of SNP2 and Carbendazim on growth of rice

Da Costa & Sharma (2016), treated with CuO NPs. Germination rate, root and shoot length and plant biomass decreased by uptaking of Copper (Cu) and increased in high concentrations of CuO nanoproduct. The work clearly demonstrated that the toxic effect of Cu accumulation in plant roots and shoots that resulted in reduction of photosynthesis.

Thounaojam et al., (2012), investigated the effects of Cu on rice plants in different concentrations for 5 days in hydroponic condition. Maximum inhibition was occurred at 100 µM Cu in shoot (18.84%) and root (27.59%) with respect to control. At the same concentration, fresh mass of shoot was decreased by 35.31% while in root 44.44% found to be decreased. He suggested that Cu toxicity is greater in root than shoot.

Yiyu et al., (2020), examined that effect of nCuO on the growth of rice. The concentration of nCuO was 62.5 mg L^{-1}, 125 mg L^{-1} and 250 mg L^{-1}. The activity of both catalase and superoxide dismutase was decreased in rice leaves treated with nCuO at the concentration of 250 mg L^{-1}, while the activity of the superoxide dismutase was significantly increased by 1.66 times in rice roots exposed to 125 mg L^{-1} nCuO.

Liu et al., (2019), conducted an experiment to determine the main effects of nCuO (0, 0.1, 1.0, 10, 50 & 100 mg L^{-1}) and Arsenic (As) (0- & 18-ml kg^{-1}) and the combined effect between nCuO and As on rice seed germination and seedling growth. As alone decreased the germination percentage. Both treatments reduced seedling shoot and root length and exhibited interactive effects. nCuO & As also produced on combined effect on the number of root branches (NRB) of rice seedlings. Notably, high nCuO concentration (50 & 100 mg L^{-1}) mitigated the negative effects of As. Cu uptake in shoots and roots was linearly correlated with Cu in the sand without As addition ($R^2 > 0.756$). Whereas, as addition to the sand produced non monotonic changes in Cu concentration in shoots and roots vs Cu concentration in the sand ($R^2 > 0.890$). As concentration in shoots had a slightly negative linear correlation with Cu concentration in the sand ($R^2 > 0.275$).

Liu et al., (2019), conducted another study to find out phytotoxicity of nCuO, As & their combination to rice plants during the life cycle. No significant effect was observed on seed germination. Significant effect was found in seedling length, growth and biomass of shoots and roots and on branch of root, and dry biomass.

Adhikari et al., (2012), resulted on experiment to evaluate the effect of nCuO on seed germination of soybean and chickpea. Different doses of Cu suspensions like 0, 5, 15, 30, 45, 60, 100, 200, 400, 600 mg L^{-1} where prepared for the experiment. The maximum seedling growth was found at 100 ppm for soybean and 60 ppm for chickpea. Beyond this concentration, the growth was inhibited. It was found that the accumulation and uptake of nano particles was dependent on the exposure concentrations of Cu nanoproducts.

Rajput et al., (2018), denoted the toxic effects of CuO NPs on plants by inhibiting seed germination and showed this nanoproducts was reduced in the shoot and root lengths, photosynthesis and respiration rate and morphological as well as enzymatic changes.

Tiwari et al., (2019), conducted hydroponic experiment to investigate impact of laser ablated CuO NPs on rice seedlings. The result showed that growth and development of rice seedlings might be beneficial in lower doses of nanoparticles.

Prasad et al., (2012), showed Zinc nano product (nZnO) (25 nm) at 1000 ppm concentration enhanced seed germination, seedling vigor, early flowering, chlorophyll content and stem-root growth.

Javadimoghadam et al., (2015), conducted a RCBD experiment on effect of different concentration of Fe and Zn chelate nano fertilizer. Results revealed that Fe and Zn chelate nano at 2 (per 1000) concentration significantly influenced on fruit number, chlorophyll content, super oxide dismutase and micro elements. The highest number of fruits, flower and chlorophyll content in leaves were obtained at 2 (per 1000) Iron (Fe) and 2.5 (per 1000) Zn concentration. He concluded that by foliar applications of liquid fertilizer could improve the plant growth of cucumber.

Srinivasan et al., (2017), found that 25 ppm of nCuO enhanced germination percentage, which seedling length and biomass were maximum at 50 ppm compared to control and $CuSO_4$ at 20 kg ha^{-1} treatment. 100 ppm concentrated nCuO recorded for maximum shoot length, but 50 ppm concentrated nCuO had significantly higher root length and nodulation of cowpea. Cu availability increased up to 100 ppm nCuO, highest availability of Zn in plant dry matter recorded at 25 ppm of nCuO.

Boonyanitipong et al., (2011), found ZnO NPs has no effect on germination percentage, observed to have detrimental effects on rice roots on early seedling stage. nZnO was found to stunt roots length and reduce root number.

Upadhyaya et al., (2017), suggested that treating rice seeds with Zn NPs protecting plants from ROS damage by promoting levels of antioxidant enzyme activities. Consequently, the Zn NPs treated seed showed better potential for germination.

Elizabath et al., (2017), conducted a field experiment. The experiment was on effect of different concentration of nFeO and nZnO. It may be concluded in combination of nZnO and nFeO (nZnO @ 100 ppm + nFeO @ 50 ppm), can give the best vegetative growth.

Bala et al., (2019), evaluated the efficiency of Zinc (Zn) nano fertilizer of rice. Application of nZnO significantly improved the plant growth.

Poornima & Rv, (2019), investigated to examine the effects of nZnO on sorghum growth. Zn nanoparticles 500 ppm spray gave greater plant height, leaf area index and total dry matter as compared to 1000 ppm bulk $ZnSO_4$.

Ramadan et al., (2020), conducted an experiment on effect of FeO and MgO NPs on soybean plant. Some positive changes were detected when FeO NPs and MgO NPs acted as nano fertilizers in this experiment.

Yasur & Rani, (2013), studied on the impact of silver nanoparticle (Ag NPs) and Silver Nitrate ($AgNO_3$) application on germination percentage, root and shoot length of *Ricinus communis L.* plant. Ag NPs had no significant effects on growth even at higher concentration of 4000 mgL^{-1} while the silver in bulk form as $AgNO_3$ applied on the seeds inhibited the seed germination. The Ag NPs and $AgNO_3$ application to seeds also caused an improved enzymatic activity of ROS enzymes and phenolic contents of seedlings. He concluded that Ag NPs had lesser toxicity in comparison to other particles in *Ricinus communis* seeds and may be used for agriculture.

Vannini et al., (2014), investigated the effects of 1 mgL^{-1} and 10 mgL^{-1} Ag NPs germinating wheat seedlings. 10 mgL^{-1} Ag NPs has negatively affected the seedling growth and induced morphological modifications in root tip cells. That means the treatments with 10 mgL^{-1} Ag NPs showed its toxicity on the early growth of wheat seedlings.

Nair & Chung, (2014), suggested that exposure to Ag NPs caused significant physiological and molecular level differences, oxidative stress and resulted in the induction oxidative stress tolerance mechanisms of rice seedlings.

Anitha & Savitha, (2015), studied on impact of Carbendazim on percent of germination, seedling length, electrical conductivity, vigor index, chlorophyll a, chlorophyll b, total chlorophyll and phenolic contents of rice cultivars. The study was carried out for 14 days after soaking the seeds in different concentration of Carbendazim. The results were root length, shoot length, vigor index increased up to 9 mg and at higher concentration it declined. Germination percentage, conductance and phenolic contents were increased. Maximum chlorophyll content was recorded at 12 mg concentration. Thus, it exhibits a degree of tolerance to fungicide.

Chaitra & Anitha, (2016), decided from her study that the seed germination, vigor index, both biochemical and morphological parameters were affected at higher concentrations of Carbendazim. The phytotoxicity or residual effect can be minimized only if the fungicide is used within the threshold level or recommended dosage.

Singh et al., (2016), found that Carbendazim causes embryotoxicity, apoptosis, teratogenicity, infertility, hepatocellular dysfunction, endocrine disrupting effects, disruption of hematological functions, mitotic spindle abnormalities, mutagenic and aneugenic effect. It also disrupted the microbial community structure in various ecosystems.

Mahajan et al., (2011), demonstrates an effect of nano ZnO (nZnO) particles on the seedlings growth of mung and gram. The maximum effect was found at 20 ppm for mung and 1ppm for gram seedlings. Beyond this concentration, the growth was inhibited. The statistically determined P value for root and shoot growth at optimum concentration was found to be less than 5%.

2.2 Effects of SNP2 and Carbendazim on yield and yield components

Gogoi et al., (2022), showed that Carbendazim 50 WP provided 62.02% increased yield over untreated (inoculated) control.

Abdul-Hadi et al., (2021), found combined Mancozeb and Carbendazim improve production in Guinea savannah of Nigeria.

Ravindra et al., (2022), found Carbendazim 50% WP can provide minimum severity of sheath blight of rice and maximum yield simultaneously.

Bhowmik & Biswas, (2022), showed Carbendazim as seed treating chemicals can provide better yield of rice.

Liu et al., (2019), conducted another study to evaluate phytotoxicity of nCuO, As & their combination to rice plants during the life cycle. Significant effect was found in effective tiller number, total grain weight, average grain weight and several other panicle parameters. nCuO increased Cu uptake and seedlings and generally improved seedling growth. Arsenic (As) in high concentration in roots and increased in shoots and seedling growth was also inhibited. nCuO & As reducd accumulation in dehusked grains. The accelerated heading stage by nCuO may help to shorten the life cycle of rice, thereby reducing As accumulation in grains.

Prasad et al., (2012), showed Zinc nano product (nZnO) (25 nm) at 1000 ppm concentration enhanced pod yield per plant was 34% higher compared to chelated bulk $ZnSO_4$.

Javadimoghadam et al., (2015), an effect of different concentration of Fe and Zn chelate nano fertilizer. Results showed that Fe and Zn chelate nano at 2 (per 1000) concentration significantly influenced on yield of cucumber.

Elizabath et al., (2017), conducted a field experiment. The experiment was on effect of different concentration of nFeO and nZnO. It may be concluded in combination of nZnO and nFeO (nZnO @ 100 ppm + nFeO @ 50 ppm), grain yield was found to be the highest in terms of maximum.

Brijbhooshan et al., (2019), studied with nZnO and revealed that direct seedling through hand dibbling under puddled condition could be an option for rice cultivation, as normal transplanting required more labour and delayed maturity compared to direct seeding. Application of nZnO foliar application at 1000 ppm is innovation to increase Zinc (Zn) content and uptake and in promoting grain yield over $ZnSO_4.7H_2O$ application.

Poornima & Rv, (2019), investigated to examine the effects of nZnO on sorghum yield and grain Zn content. Grain yield was 9.5% higher in 500 ppm of Nano foliar spray as compare with 1000 ppm of Bulk foliar spray.

Bala et al., (2019), evaluated the efficiency of ZnO NPs as Zinc (Zn) nano fertilizer of rice. Application of nZnO significantly improved the yield and yield attributing characters in rice CV.PR-121 grown in Zn deficient soil. It showed enhanced yield and grain Zn contents of rice plant besides improvement of the chemical and microbial characteristics of Zn deficient soil.

Kumar et al., (2017), concluded from his research that Carbendazim which used in seed treatment along with two foliar sprays of propiconazole at booting and milking stage has enhanced disease control and decreases yield losses effectively.

Balgude & Gaikwad, (2018), found recommendation as an IDM module for effective management of leaf blast, neck blast and node blast diseases of rice and increasing the grain and straw yields of paddy as well as monitoring return from seed treatment with benomyl (0.3%) and *Pseudomonas flouresences* (0.5%) to rice seeds with soil application of rice husk Ash (RHA) and Rice straw and at transplanting followed by three sprays of propiconazole (0.1%) or Carbendazim (0.1%) at 15 days interval.

Li et al., (2020), evaluated the potential risks of this fungicide in agricultural production and application. The result showed that *Caenorhabdities elegans* was inhibited by 0.01 µg/L Carbendazim. The treatment of 0.1 µg L^{-1} carbendazim caused a significant reduction in locomotion behavior and significant damage to the reproductive and antioxidant system, causing the lifespan of nematodes to be drastically shortened. These results provide a better understanding of the environmental risk of carbendazim and raise new concerns about safety.

Ghidan et al., (2019) reported silver nanomaterials have some adverse effect on plant growth apart from the antimicrobial properties.

Lemraski et al., (2017), conducted an experiment as split factorial in RCBD with three replications in Sari, Iran during 2013 & 2014. They showed that nano particle consumption in Tarom Mahali and Tarom Hashemi resulted in improved yield.

Singh et al., (2015), showed that Flusilazole 12.5% + Carbendazim 25%SE (NS) at 0.05% concentration was found highly effective against sheath blight of rice and gave good result with 40.70 qt/ha. It was also effective at 0.02% concentration. Other fungicides such as Carbendazim 25% + Flusilazole 12.5% SE (Luster) and Kresoxime-methyl 44.3% SC (Ergon) at 0.05% were reduced the disease incidence and increased the yield as 37.96 qt ha^{-1} and 36.00 qt ha^{-1} respectively.

Muthukumar et al., (2019), conducted an experiment, among the different treatments, Carbendazim 50%WP @.650g ha^{-1} recorded significantly highest grain yield of 9.00 t ha^{-1} in Carbendazim 50%WP @ 500 g ha^{-1} (8.85 t ha^{-1}) and 250 g ha^{-1} (8.76 t ha^{-1}).

2.3 Effects of SNP2 and Carbendazim on environment

Sun et al., (2012), conducted on experiment on evaluation the potential toxicity of several type of commonly used metal oxide nanoparticles (NPs) in three different lines. He found that Copper Oxide (CuO) NPs caused significant cell death while Iron Oxide (FeO), Titanium Oxide (TiO_2) and silica NPs showed a little or no cytotoxic effect. CuO NPs appeared to have greater cytotoxicity compared to their bulk counterpart and to other metal oxide nano products.

Shi et al., (2018), found from the study on effects of Cu NPs on paddy soil and decided that CuO NPs severally inhibited the microbial activity in soil and the organic matter could partly mitigate the negative effects of CuO NPs.

Phogat et al., (2016), said a nanoparticle might possess a beneficial effect for the flora while it can have hazardous effects on the fauna. A particular nanoparticle can be beneficial to the plants and soil microflora at a particular concentration while the same exhibits the opposite effects at a high concentration.

Ahamed et al., (2014), studied on antimicrobial activity of copper oxide nanoproducts (CuO NPs). It was analyzed against different Bacteria. He concluded that CuO NPs demonstrated excellent antimicrobial activity against a range of bacteria, the strains susceptible to CuO NPs exhibited larger zone of inhibition, whereas resistant strains exhibit smaller zone of inhibition.

Liu et al., (2019), suggested that transforming Cu containing into their nano forms. On the nano scale, antimicrobial properties of Cu are improved due to tremendous increase in the surface area to volume ratio. The release of Cu-containing nanoparticles into the water. Thus, the amount of Cu is also slower from the Cu NPs into the water. The beneficial and toxic properties of nCuO depends on interaction with other environmental components and plant species. He provides the result on implications in sustainable development by combining the applications of nCuO as pesticides, fertilizers and amendments counteracting As toxicity. The threefold benefits may also give advantages to nCuO over other mitigation agents of As phytotoxicity.

Ren et al., (2008), showed the activity of nCuO against a range of bacterial pathogens with minimum bacterial concentrations (MBCs) ranging from 100 µg ml^{-1} to 5000 µg ml^{-1}. The ability of CuO nanoparticles to reduce bacterial populations of zero was enhanced in the presence of sub-MBC concentrations of silver nanoparticles (AgNPs).

Jamdagni et al., (2018), decided the combination of fungicides and ZnO NPs will not only be effective against fungal pathogens in smaller concentration and less prone to development of resistance, but also ZnO mediated degradation of fungicides could provide for a technique for removal of fungicides from the environment.

Srinivasan et al., (2017), conducted a net house experiment on seed treatment of cowpea by applying nCuO and nZnO (25 ppm, 50 ppm, 100 ppm & 200 ppm) nCuO and (250 ppm, 500 ppm & 750 ppm) nZnO were taken.It has no significant difference of nCuO on soil microbiological properties up to 100 ppm. Total bacterial count (TBC) was observed at 200 ppm of nCuO. nZnO treatments (up to 750 ppm) all microbiological parameters studied were higher compared to control.

Boonyanitipong et al., (2011), he showed that direct exposure to specific types of nano-particles causes significant phytotoxicity, emphasis the need for ecological responsible disposal of wastes containing nanoparticles and also highlights the necessity for further study on the impacts of nanoparticles on agricultural and environmental system.

Sharma et al., (2017), analyzed on Magnesium Oxide nano-product (MgO NPs) and found that pathogenic strains were susceptible to MgO NPs, which confirmed their potential effectiveness against other bacterial strains.

Ogunyemi et al., (2019), studied on MgO (18.2 nm) and MnO_2 (16.8 nm) which were synthesized from *Matricaria chamomilla L* extract. The MgO and MnO_2 nanoparticles (MgO

NPs and MnO_2 NPs) reduced the growth of *Acidovorax oryzee* strain RS-2 by 62.9% &71.3% respectively. The flow cytometry observation revealed that the apoptotic cell ratio of RS-2 increased from 0.97% to 99.52% & 99.94% when treated with nMgO and $nMnO_2$ respectively. He suggested that the synthesized MgO NPs & MnO_2 NPs could serve as an alternative method for the management of Bacterial Brown Strips (BBS).

Rastogi et al., (2019), showed that Si-NPs have the potential to revolution the existing technology used in Agriculture. These nano particles are useful for developing new cultivars that are resistance to biotic and abiotic factors. These can provide green and eco-friendly alternatives to various chemical fertilizers and pesticides without hampering nature.

CHAPTER III

MATERIALS AND METHODS

The field experiment was conducted at the Agronomy field and laboratory, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka- 1207 during the period from December, 2019 to May, 2020. Details of different materials used and methodologies followed in the experiment are presented in this chapter.

3.1 Description of the experimental site

3.1.1 Location

The field is geographically located at 23^0 $77^/$ N latitude and 90^0 $35^/$ E longitude at an altitude of 8.6m above mean sea level under the Agro-ecological zone of Madhupur tract (AEZ No.28). The experimental area is facilitated with sufficient sunshine with having available irrigation and drainage system during the period. The location of the experimental site has shown in Appendix I.

3.1.2 Soil

The soil of the experimental area belonged to the Madhupur tract (AEZ No.28). It was a medium high land with non-calcareous dark grey soil with low organic matter content. The P^H value of the soil was 5.6. The characteristics of the experimental soil have been shown in Appendix II.

3.1.3 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during April to September, but scanty rainfall associated with moderately low temperature prevailed during October to March. The detailed meteorological data were recorded by Bangladesh Meteorological Department, Dhaka for the period of experimentation have been presented in Appendix III.

3.2 Description of the test crop

Two varieties of transplanted Boro rice were selected for our research. The varieties were –

(1) BRRI dhan28

(2) BRRI dhan63

3.2.1 BRRI dhan28

It is a mega-variety of Boro rice. It is medium in size and slender in shape, white color, life cycle in 140 days. Yield is (5.5-6.0) ton ha^{-1} (Bangladesh Rice Knowledge Bank, BRRI). In our experiment, we considered this variety as V_1.

3.2.2 BRRI dhan63

It is a transplanted Boro rice and High Yielding Variety (HYV) too. Its yield is (6.5-7.0) ton ha^{-1}, Life cycle is (148-150) days. The rice looks like "Basmoti" rice in Pakistan. No shattering is occurred (Bangladesh Rice Knowledge Bank, BRRI). In our experiment, we considered it as V_2.

3.3 Treatment

3.3.1 Treatment

Two rice varieties (BRRI dhan28 and BRRI dhan63) and a Nanoproduct (Stalwart Nano product2 [SNP2]) were considered as factors of the experiment. The Stalwart Nano product2 [SNP2] is an eco-friendly formulation which is made up off Copper (Cu), Magnesium (Mg) and Zinc (Zn). By supplying these essential micronutrients, better yield can be achieved. It has an ability to mix with other pesticides. The Nanoproduct were applied with 07 levels of which were denoted by T_0 – control (only water); T_1 – Carbendazim @ 2g L^{-1}; T_2 –SNP2 @ 1.0 ml L^{-1}; T_3 – SNP2 @ 2.0 ml L^{-1}; T_4 –SNP2 @ 3.0 ml L^{-1}; T_5 – Carbendazim @ 2g L^{-1}+ SNP2 @ 1.0 ml L^{-1} and T_6 – Carbendazim @ 2g L^{-1}+ SNP2 @ 2.0 ml L^{-1}. It is noted that Carbendazim is a fungicide against bacterial leaf blight and blast disease in rice. So, we made several combinations with SNP2 as treatment in our experimentation. SNP2 is an eco-friendly formulation which is made up off Copper (Cu), Magnesium (Mg) and Zinc (Zn). By supplying these essential micronutrients, better yield can be achieved. It has an ability to mix with other pesticides.

However, the solution of SNP2, Carbendazim and their mixed solution were prepared in the laboratory. On the basis of the recommendation rate, we prepared 2 Litre (L) of each solution for foliar application by spraying in each plot. 2 L solution was applied in 6 plots or 720 hills of rice plants.

3.3.2 Application of treatment

At first the treatments were applied at 19 February when the plants were 25 days old on the main field. They were applied by 5 times at 15 days interval (e.g. 19 February, 05 March, 20 March, 4 April, 20 April respectively). We used a plastic board to prevent the spray drift to be deposited onto plants of the neighboring plots.

3.4 Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD). The replication number was three. The plot number was 42 (2×7×3). Individual plot size was $4m^2$ (4m×1m). Each replication was divided into 14 plots. with the help of statistical random number table. The drain size between 2 replications was 1m and the gap between 2 plots was 0.5m. Field layout was prepared at 22 January, 2020 for transplanting the seedlings. The layout of the experiment has given in Appendix IV.

3.5 Description of our total work from sowing to harvesting

3.5.1 Seed collection, sprouting and sowing

Seeds of the rice varieties were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. According to recommendation, for both varieties seed rate is 10kg ac^{-1}. Our field size was 330 m^2. After calculation, we got 412.5g seed for each variety was needed. The required seeds were soaked in water for 24 hours and after soaking these were kept tightly in jute stack air for 4 days. When about 90% of the seeds were sprouted, it were sown uniformly in well-prepared wet nursery bed on 14 December, 2019.

3.5.2 Transplantation of seedlings

The experimental field was opened by a tractor before 10 days of transplanting. Then it was ploughed well to make the soil nearly ready for transplanting. Weeds and stubbles were removed and the field was levelled by laddering. Then the layout was done before 3 days of transplanting and fertilizers (urea, TSP, MoP, Gypsum and $ZnSO_4$)and were applied as basal dose before 1 day of transplanting. Transplanting was done at 25 January, 2020 when the seedlings were 42 days old. The spacing for our crop was (20 cm ×15 cm) and we planted 3 seedlings $hill^{-1}$ (Bangladesh Rice Knowledge Bank, BRRI).

3.5.3 Fertilizer application

Recommendation of Bangladesh Rice Knowledge Bank has been followed for fertilizer practice in our experiment. All the required amounts of fertilizers except were applied as basal dose. Urea was top dressed in each plot by 3 equal splits at 15, 30 and 45 DAT (Days After Transplanting). The recommended dose of fertilizer is shown in Appendix V.

3.5.4 Intercultural operation

We tagged our field one the day after of transplanting. We used 2 sided colored tag for easy identification. One side was the indicator of variety and another side was the indicator of treatments. We used white color for V_1 and light blue color for V_2. Another side of each tag was colored by different strains for identification of treatments. Black for T_0, yellow for T_1, green for T_2, blue for T_3, red for T_4, violet for T_5 and orange for T_6 were selected for our experiment. We tagged the same-colored tag at our spray machine for each treatment so that one could identify the variety and treatment from far.

3.5.4.1 Gap filling

Gap filling was done at 4 times, 28 January, 3 February, 9 February and 11 February respectively. Gap filling was needed for maintaining accurate number of populations.

3.5.4.2 Weeding

Weeding was done to keep the plot weed free up to 40 days for allowing the maximum nutrients advantage to the crops. We weeded our field for 6 times; 11 February, 17 February, 24 February, 26 February, 02 March and 08 March respectively. At the time of weeding, we removed the dried *Azolla* which was compacted the base of rice plant at 02 March. We weeded our field by hand pulling and sometimes-used nirani or khurpi. At the time of hand pulling, the soils were loosen for proper root expansion.

3.5.4.3 Roguing

At 19 February, 2020, some plants were seen with abnormal growth. So they were removed from the plot by hand pulling.

3.5.4.4 Irrigation

We followed Alternate Wetting and Drying method (AWD) for better yield at a low cost. In addition, tillering, panicle initiation and development stages had been done continuous irrigation.

3.5.4.5 Drainage

Excess water was removed from the field when it was necessary.

3.5.4.6 Pesticide application

For removing pest and nematode, we used Ektara at 22 March and Diazinon at 6 April.

3.5.5 Harvesting

Harvesting was done at 12 May, 2020. We selected 5 random plants for recording data on yield components and $1m^2$ land from each plot for measuring grain and straw yield data. We harvested our samples separately for calculation of yield and yield components. When 85% to 90% of the grains became golden yellow in color, the crop was harvested.

3.5.6 Post – harvest operation

Different bundles from each plot were cut separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and grains were cleaned and sample plants were kept separately for data collection.

3.6 Data collection

First of all, we eliminated the border rows from 4 sides for avoiding border effect. Therefore, 4 rows were remained from 6 rows for selecting samples. Then one row after border rows from one side was selected as destructive row. From this row, we collected 2 plants before each treatment for dry matter (g) calculation. So, 3 rows from each plot were remained for growth and yield measurement. We selected $1m^2$ areas among the 3 rows for yield calculation. From the rest plants of three rows, we selected 5 sample plants for collecting data on growth and yield components and continued to collect data before each treatment. We collected our data on –

3.6.1 Growth

I. Plant height
II. Dry matter

3.6.2 Yield component

I. Number of tiller hill^{-1}
II. Percent of effective tiller and non-effective tiller hill^{-1}
III. Filled grains panicle^{-1}
IV. Unfilled grains panicle^{-1}
V. 1000-seed weight

3.6.3 Yield

I. Straw yield
II. Economic or grain yield
III. Biological yield
IV. Harvest index

Work schedule for experimentation was shown in Appendix VI.

3.7 Procedure of sampling for growth study during the crop growth period

3.7.1 Plant height

The height of the rice plants had recorded from 25 DAT before the first treatment, it continued at 15 days interval up to 4th treatment before panicle initiation, and another height was recorded at the time of harvesting. The plant height data was measured from the ground level up to tip of the flag leaf. At the time of harvest, the plant height data was collected from the ground level up to the tip of panicle. From height of the 5 plants, one data was found by calculating mean for the plot. Then the 3 data from 3 replications were calculated for getting average plant height for the combination.

3.7.2 Dry matter

We collected 2 plants from destructive row side by side from 40DAT after checking the first effects of treatment to harvesting at 15 days interval. We collected two plants with roots and washed them for removing soils which are adjacent to the root, then We dried it on sunlight. When the excess water was removed from the plants, then it transferred to the oven for oven dry. After 72 hours, we collected the samples from oven and weighted it. The process was for continued for individual plot. Same combinations were calculated average from 3 replications. From continuous collecting dry matter, we collected the dry matter weight (g).

3.8 Procedure of sampling for yield components study after harvesting

3.8.1 Total number hill^{-1}

Total number of tillers was recorded from 25 DAT at 15 days interval up to harvesting. The average number of 5 hills were considered as total tiller number hill^{-1} for the plot and from 3 replications, we got total tiller number hill^{-1} for each combination.

3.8.2 Effective tiller hill^{-1}

Effective tiller means that tiller has ability to produce panicle. Therefore, it is also called number of panicle hill^{-1}. We counted the number of effective tillers per hill. It is counted from 5 selected hills.

3.8.3 Number of filled grains and unfilled grains panicle^{-1}

From randomly selected 5 hills, number of filled grains and unfilled grains were counted. For each panicle of each hill was counted separately. Then, the data from average number, we got filled grains and unfilled grains for each hill. We calculated the average of 5 hills and got the data for each plot. Then We got the average for this combination for 3 replications.

3.8.4 1000-grain weight

One thousand cleaned dried filled grains were randomly collected from the seed stock obtained from 5 hills of each plot and dried in an oven at 14% moisture content and weight by electric balance.

3.9 Procedure of sampling for yield study after harvesting

3.9.1 Grain and straw yield

Grain and straw yield were collected from 1m^2 were taken separately from each plot and dried in the oven at 80±5^0 C until a constant weight was obtained. This was done to find out the moisture percentage of grain and straw samples. The grain and straw yield were adjusted at 14% level of moisture by using the formula suggested by Abedin and Chowdhury (1982). % Moisture Content (MC) = $\frac{Fresh\ weight - oven\ dry\ weight}{Fresh\ weight} \times 100$

So, adjusted yield per plot at 14% moisture content = $\frac{100-\%MC}{86}$×w [100-14 = 86]

Here, MC = Present moisture content of grain or straw

W = Fresh weight of yield

The yield per hectare was then determined as follows –

Yield (t ha^{-1}) = $\frac{Adjusted\ yield\ /plot(g)}{1000g\times1000kg}\times\frac{10000\ \mathrm{m2}}{Harvested\ plot\ area\ (\mathrm{m2})}$

3.9.2 Biological yield

Biological yield was calculated by using the following formula –

Biological yield = Grain yield + straw yield

3.9.3 Harvest index

Harvest index is the relationship between grain yield and biological yield (Gardner et al., 1985). It was calculated by using the following formula –

Harvest Index (HI) (%) = $\frac{Grain\ yield}{Biological\ yield}\times100$

3.10 Statistical analysis

The recorded data were subjected to statistical analysis. Analysis of variance was done following RCBD (factorial analysis) with the help of computer package CROPSTAT by following "Balanced ANOVA Table". We did our mean separation among the treatments by Least Significant Difference (LSD) test at 5% level of significance. LSD was calculated as of the equation below:

Least Significant Difference (LSD) = $\frac{\sqrt{2}\times EMS}{No.of\ observation/Mean}\times t_{0.05}$

From the LSD value, lettering has done for variety, treatment and combination of variety and treatment. Lettering helps us to select the statistical similarity and dissimilarity among the treatment effects on different parameters.

For collecting the effectiveness of our sampling, we collected our CV (Co-efficient of Variance) for each parameter from this formula –

Co-efficient of Variance (CV) = $\frac{\sqrt{EMS}}{GM}\times100$

Here, CV = Co-efficient Variance

EMS = Error Mean Square

GM = Grand Mean

In addition, we ranked and scored the treatments based on each parameter for individual variety, treatments and combination by following Matrix ranking and scoring. From the highest and the lowest scoring, we suggested the best treatment applied in each variety.

CHAPTER IV

RESULT AND DISCUSSION

The chapter comprises presentation and discussion of the results obtained from a study to investigate the effect of nano products on growth, yield and yield components of Boro rice. The Boro rice has two varieties in our research- BRRI dhan28 and BRRI dhan63. The results of the growth, yield components and yield parameter of the crop as influenced by different concentration of nano products, Carbendazim and mixed solution of Carbendazim and nano products and possible interpretations have been presented and discussed in this chapter.

4.1 Discussion on growth parameter

4.1.1 Plant height (cm)

4.1.1.1 Varietal effect on plant height (cm) of Boro rice

The bar chart below shows the varietal effect on plant height (cm) of Boro rice at different days after transplanting. At 25 DAT, BRRI dhan63 (V_2) was better than BRRI dhan28 (V_1), but at 40 DAT and 55 DAT, both showed similar plant height (cm) statistically, moreover, V_1 showed the greatest value at 150 DAT (at harvest) in this parameter both mathematically and statistically (Fig 1). First three DAT data showed non-significant difference but last two DAT data showed significant difference at 26df at 5% level of significance (Appendix VII to XI).

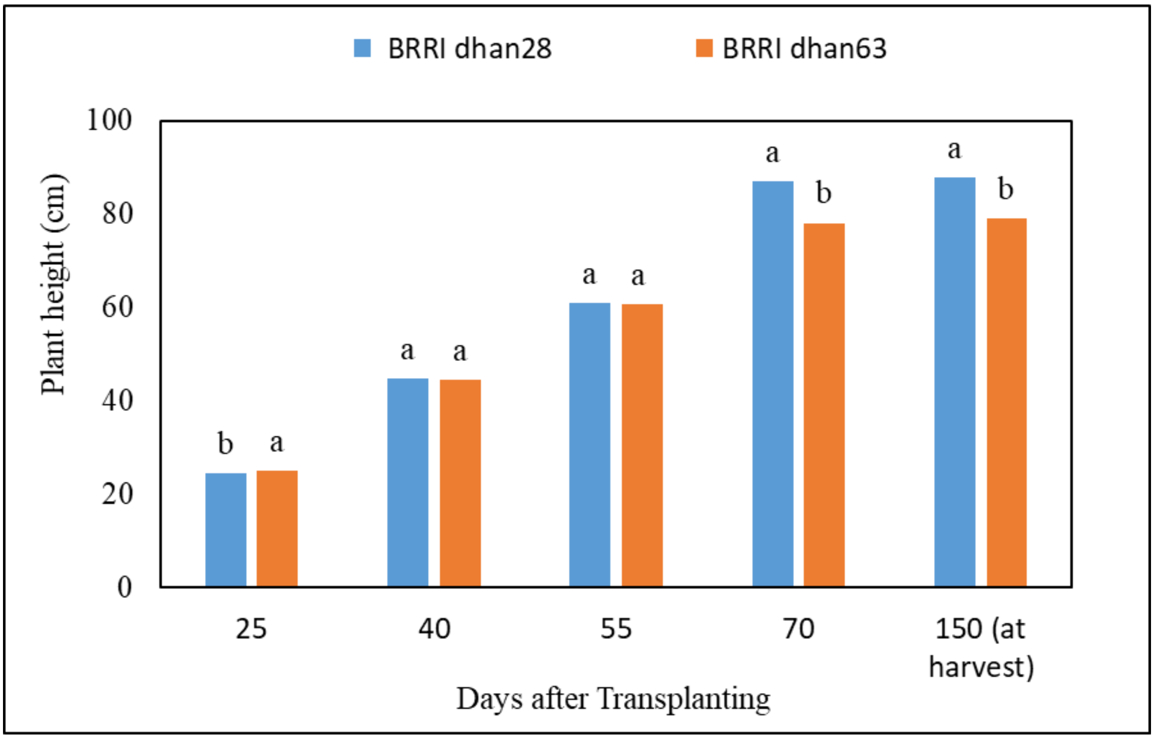

Figure 1: Varietal effect on plant height (cm) of Boro rice at different days after transplanting

For 25DAT, LSD $_{(5\%)}$ = 0.62, CV (%) = 3.96%; For 40DAT, LSD $_{(5\%)}$ = 0.58, CV (%) = 2.06%; For 55DAT, LSD $_{(5\%)}$ = 0.71, CV (%) = 1.85%; For 70DAT, LSD $_{(5\%)}$ = 1.42, CV (%) = 2.71%; For 150DAT, LSD $_{(5\%)}$ = 1.49, CV (%) = 2.82%;

4.1.1.2 Effects of SNP2 and Carbendazim on plant height (cm) of Boro rice

The line graph shows the effect of SNP2 and Carbendazim on plant height of Boro rice at different days after transplanting. At 25 DAT, T_6 showed the highest value, it was statistically similar with T_2 and T_3 and the lowest plant height (cm) was found in T_1 but it was statistically similar with T_4; At 40 DAT, Results revealed T_0 showed the highest value and it was statistically similar with T_1 and T_2, the lowest value was in T_5 and it was statistically similar with T_4. At 55 DAT, T_1 showed the best result and it was statistically similar with T_2, T_3 and T_4 as well as T_5 had the lowest value and it was statistically similar with T_0, T_4 and T_6, here the growth rate of T_1, T_2 and T_5 would be unchanged from 40 DAT to 55 DAT. At 70 DAT, T_5 showed the best result and it was statistically similar with T_2 and T_0; T_6 showed the lowest result and it was statistically similar with T_0, T_1, T_3 and T_4, here the growth rate of T_5 was increased very rapidly, the same trend was continued up to 150 DAT (at harvest) and the plant height (cm) showed the highest value in T_5 and the lowest value was found in T_6 both mathematically and statistically (Fig 2). The all days after transplanting data had non-significant difference at 26df at 5% level of significance (Appendix VII to XI). Liu et al., (2019), found significant effect was found in length of seedling shoots and roots and on root branching, seedling growth in case of nCuO, most probably the plant height (cm) increased because of it.

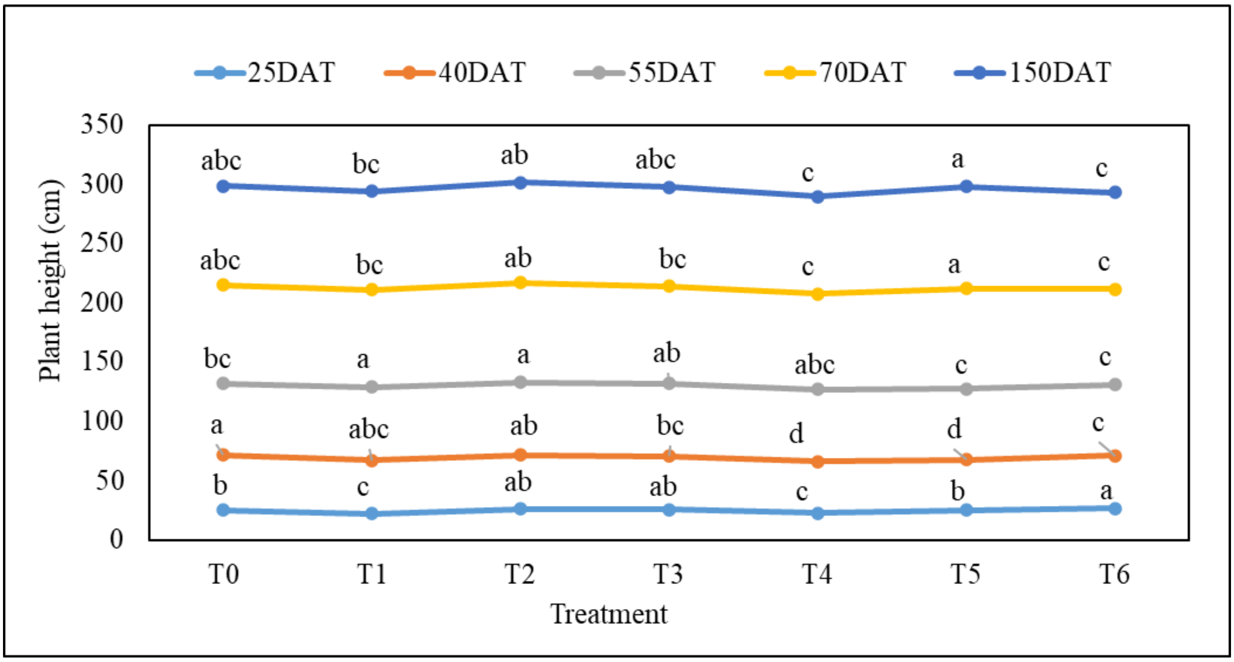

Figure 2: Effects of SNP2 and Carbendazim on plant height (cm) of Boro rice at different days after transplanting

T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2; For 25DAT, $LSD_{(5\%)}$ = 1.16, CV (%) = 3.96% ; For 40DAT, $LSD_{(5\%)}$ = 1.09, CV (%) = 2.06% ; For 55DAT, $LSD_{(5\%)}$ = 1.33, CV (%) = 1.85% ; For 70DAT, $LSD_{(5\%)}$ = 2.65, CV (%) = 2.71% ; For 150DAT, $LSD_{(5\%)}$ = 2.79, CV (%) = 2.82%;

4.1.1.3 Combined effect of treatments on plant height (cm) of Boro rice

The line graph demonstrates the combined effect of treatments on plant height of Boro rice at different days after transplanting. The data had no significant difference at 26df at 5% level of significance (Appendix VII to XI). At 25 DAT, V_2T_5 showed the best result and it was statistically similar with V_1T_6, V_1T_3, V_2T_6, V_1T_2, V_1T_0 and V_2T_2 as well as V_1T_1 revealed the lowest result, it was statistically similar with V_1T_4; At 40 DAT, V_1T_3 showed the highest result, it was statistically similar with V_1T_0, V_1T_2, V_2T_0, V_2T_1, V_2T_6 and V_2T_2, The lowest result was found in V_1T_5, it was statistically similar with V_2T_4 and V_2T_3; At 55 DAT, V_2T_4 showed the highest result and it was statistically similar with V_1T_0, V_1T_1, V_1T_2 and V_1T_3 as well as the lowest value was found in V_2T_0, it was similar with V_1T_4 and V_1T_5 statistically; At 70 DAT, V_1T_5 revealed the highest result and V_1T_3, V_1T_2, V_1T_0 and V_1T_1 were statistically similar as well as V_2T_3 showed the lowest result and it was statistically similar with V_2T_1, V_2T_4, V_2T_6,

V_2T_0 and V_2T_5; At 150 DAT (at harvest), V_1T_5 was found as the highest value and it was statistically similar with V_1T_3, V_1T_2, V_1T_0 and V_1T_1 as well as the lowest one was V_2T_3 and V_2T_2, V_2T_5, V_2T_4, V_2T_0, V_2T_6 and V_2T_1 were statistically similar. The plant height (cm) increasing rate was maintained in V_1T_3, V_1T_2, V_1T_0 from 25 DAT to 150 DAT (at harvest) and this value was the highest among all combination (Fig 3).

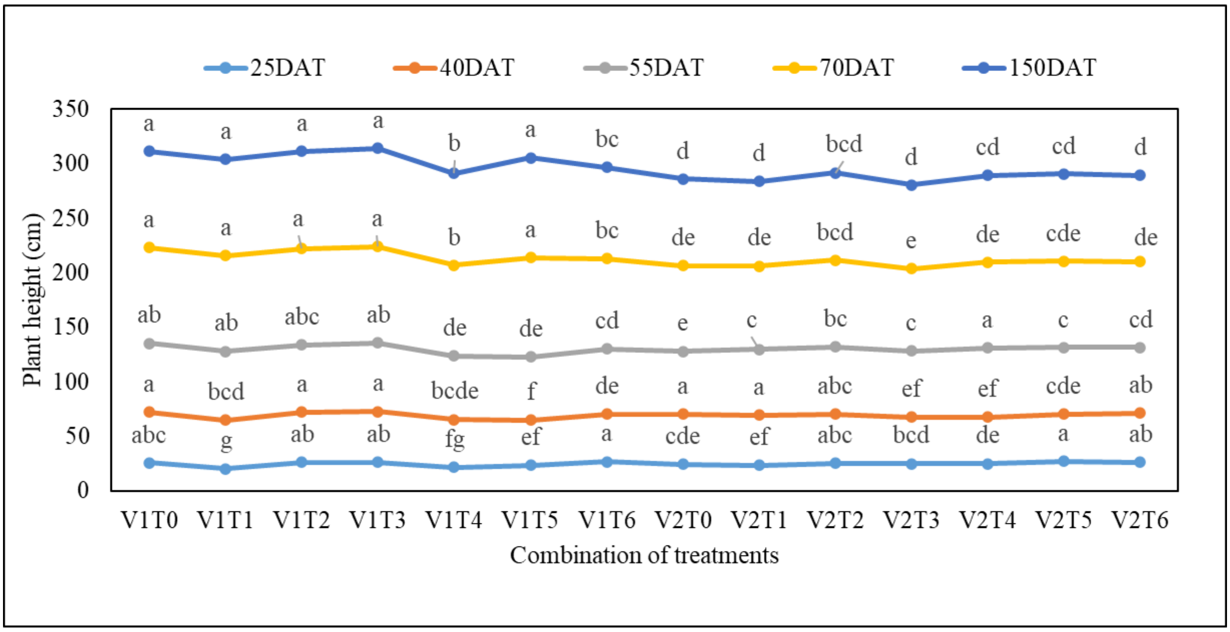

Figure 3: Combined effect of treatments on plant height (cm) of Boro rice at different days after transplanting

V_1 = BRRI dhan28; V_2 = BRRI dhan63; T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2; For 25DAT, $LSD_{(5\%)}$ = 1.65, CV (%) = 3.96%; For 40DAT, $LSD_{(5\%)}$ = 1.54, CV (%) = 2.06% ; For 55DAT, $LSD_{(5\%)}$ = 1.88, CV (%) = 1.85% ; For 70DAT, $LSD_{(5\%)}$ = 3.75, CV (%) = 2.71%; For 150DAT, $LSD_{(5\%)}$ = 3.95, CV (%) = 2.82%;

4.1.2 Dry matter (g)

4.1.2.1 Varietal effect on dry matter (g) of Boro rice

The bar chart represents the varietal effect on dry matter (g) of Boro rice at different days after transplanting. At 40 DAT, 55 DAT, 70 DAT and 150 DAT (at harvest) BRRI dhan63 (V_2) was better than BRRI dhan28 (V_1) (Fig 4). All days after transplanting data showed significant result at 26df at 5% level of significance (Appendix XII to XV).

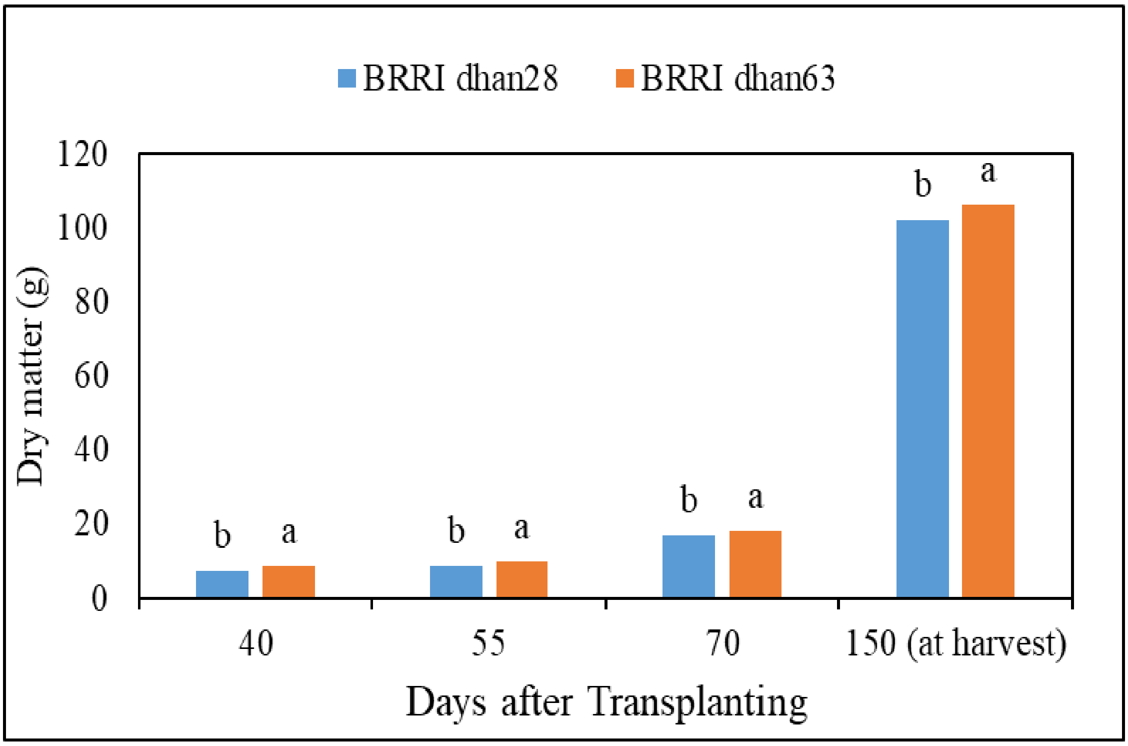

Figure 4: Varietal effect on dry matter (g) of Boro rice at different days after transplanting

For 40DAT, LSD $_{(5\%)}$ = 0.31, CV (%) = 6.16%; For 55DAT, LSD $_{(5\%)}$ = 0.63, CV (%) = 10.76%; For 70DAT, LSD $_{(5\%)}$ = 0.45, CV (%) = 4.01%; For 150DAT, LSD $_{(5\%)}$ = 0.95, CV (%) = 1.44%;

4.1.2.2 Effects of SNP2 and Carbendazim of dry matter (g) of Boro rice

The line graph shows the effect of SNP2 and Carbendazim on dry matter (g) of Boro rice at different days after transplanting. At 40 DAT, T_3 showed the highest value, it was statistically similar with T_6 and the lowest dry matter (g) was found in T_4 both mathematically and statistically. At 55 DAT, Results revealed T_2 showed the highest value, the lowest value was in T_5 and it was statistically similar with T_4. At 70 DAT, T_6 showed the best result and it was statistically similar with T_2 as well as T_5 had the lowest value. Here the dry matter (g) accumulation rate of T_5 would be unchanged from 55 DAT to 70 DAT. At 150 DAT, T_6 showed the best result and it was statistically similar with T_2 and T_3; T_1 showed the lowest result not only mathematically but also statistically. Here the growth rate of T_5 was increased after 70 DAT and T_1 showed the lowest result at harvest (Fig 5). The all days after transplanting data had non-significant difference at 26df at 5% level of significance (Appendix XII to XV). Poornima & Rv, (2019), found nZnO 500 ppm spray gave higher total dry matter as compared to 1000 ppm bulk $ZnSO_4$, most probably the dry matter (g) is increased in case of nZnO in this experiment.

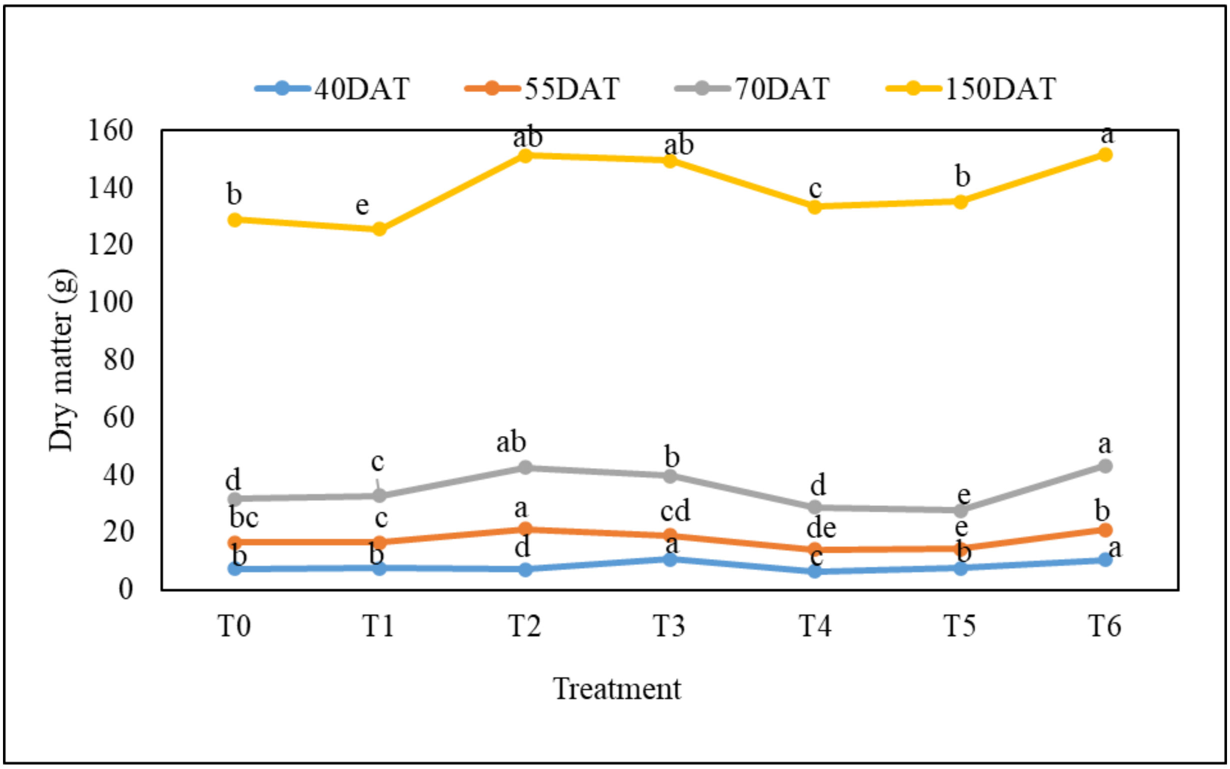

Figure 5: Effect of SNP2 and Carbendazim on dry matter (g) of Boro rice at different days after transplanting

T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2; For 40DAT, $LSD_{(5\%)}$ = 0.59, CV(%) = 6.16% ; For 55DAT, $LSD_{(5\%)}$ = 1.18, CV(%) = 10.76% ; For 70DAT, $LSD_{(5\%)}$ = 0.84, CV(%) = 4.01% ; For 150DAT, $LSD_{(5\%)}$ = 1.78, CV(%) = 1.44%;

4.1.2.3 Combined effect of treatments on dry matter (g) of Boro rice

The line graph demonstrates the combined effect of treatments on dry matter (g) of Boro rice at different days after transplanting. The data had not significant difference at 26df at 5% level of significance (Appendix XII to XV). At 40 DAT, V_2T_3 showed the best result as well as V_1T_4 revealed the lowest result, it was statistically similar with V_1T_2 and V_1T_0; At 55 DAT, V_1T_2 showed the highest result and the lowest result was found in V_1T_1, it was statistically similar with V_2T_3, V_1T_4 and V_1T_5; At 70 DAT, V_1T_2 showed the highest result and it was statistically similar with V_2T_3 as well as the lowest value was found in V_1T_5, it was similar with V_1T_4, V_1T_1 ,$V_1T_0$and V_2T_5 statistically; At 150 DAT, V_2T_6 revealed the highest result as well as V_1T_1 showed the lowest result and it was statistically similar with V_2T_1; The dry matter (g) increasing rate was maintained in V_1T_4 from 40 DAT to 70 DAT (at harvest) and this value was the lowest among all combination, but after 70 DAT the dry matter accumulation started to increase rapidly and then V_2T_1 achieved the lowest position (Fig 6).

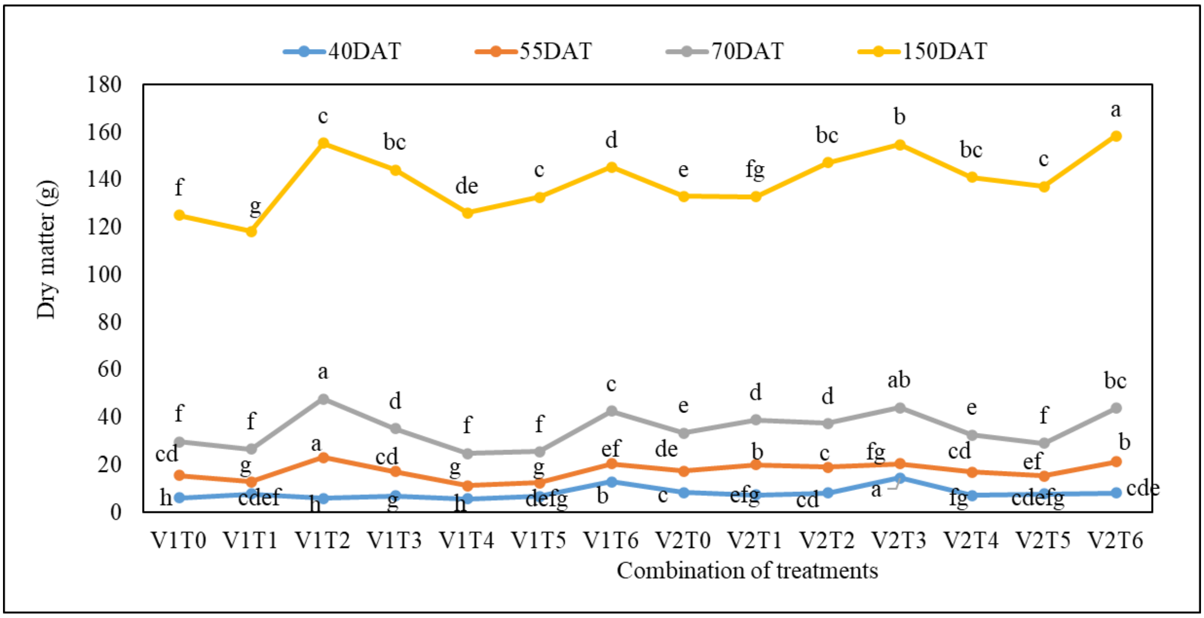

Figure 6: Combined effect of treatments on dry matter (g) of Boro rice at different days after transplanting

V_1 = BRRI dhan28; V_2 = BRRI dhan63; T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2; For 40DAT, $LSD_{(5\%)}$ = 0.84, CV (%) = 6.16% ; For 55DAT, $LSD_{(5\%)}$ = 1.67, CV (%) = 10.76% ; For 70DAT, $LSD_{(5\%)}$ = 1.19, CV (%) = 4.01%; For 150DAT, $LSD_{(5\%)}$ = 2.52, CV (%) = 1.44%;

4.2 Discussion on yield components of Boro rice

4.2.1 Total tiller number hill^{-1}, percent of effective tiller hill^{-1}, percent of non-effective tiller hill^{-1}

4.2.1.1 Varietal effect on total tiller number hill^{-1}, percent of effective tiller hill^{-1}, percent of non-effective tiller hill^{-1} of Boro rice

The bar chart represents the varietal effect on total tiller number hill^{-1} of Boro rice at different days after transplanting. At 40 DAT, 55 DAT, 70 DAT and 150 DAT (at harvest) BRRI dhan63 (V_2) and BRRI dhan28 (V_1) produced similar number of total tiller number hill^{-1} both mathematically and statistically (Fig 7). All days after transplanting data showed non-significant result at 26df at 5% level of significance (Appendix XVI to XX).

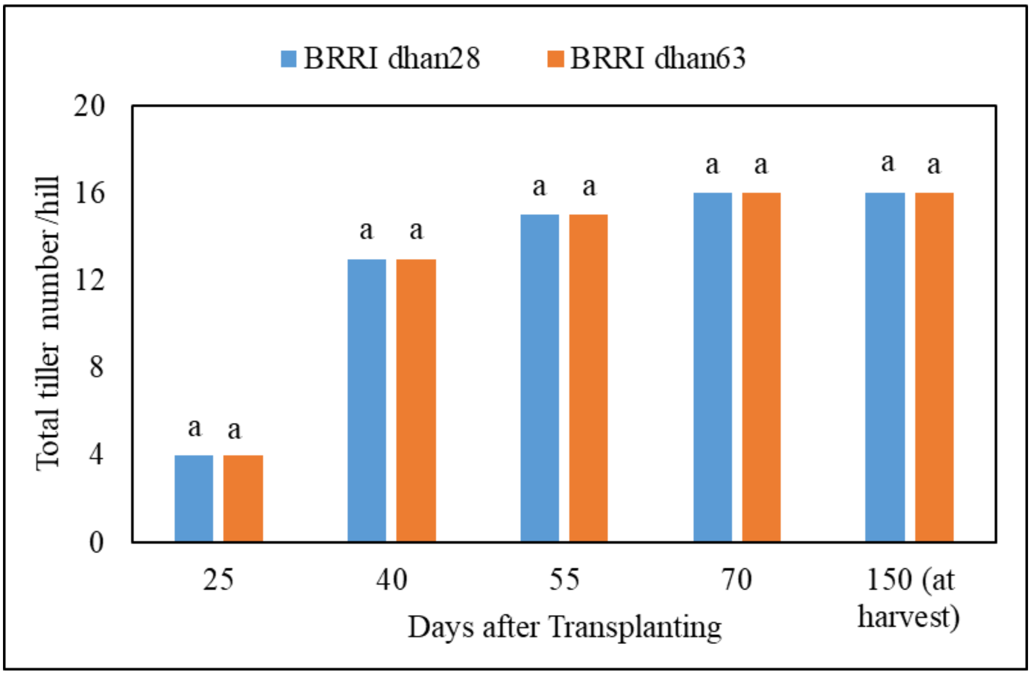

Figure 7: Varietal effect on total tiller number hill^{-1} of Boro rice at different days after transplanting

For 25DAT, LSD $_{(5\%)}$ = 0.35, CV (%) = 14.33%; For 40DAT, LSD $_{(5\%)}$ = 0.67, CV (%) = 8.16%; For 55DAT, LSD $_{(5\%)}$ = 0.56, CV (%) = 5.92%; For 70DAT, LSD $_{(5\%)}$ = 0.61, CV (%) = 6.03% ; For 150DAT, LSD $_{(5\%)}$ = 0.61, CV (%) = 6.03%;

The bar chart represents the varietal effect on percent of effective tiller hill^{-1} of Boro rice. At 150 DAT (at harvest) BRRI dhan63 (V_2) and BRRI dhan28 (V_1) produced similar number of effective tiller hill^{-1} both mathematically and statistically (Fig: 8). This data showed non-significant result at 26df at 5% level of significance (Appendix 21). The bar chart also represents the varietal effect on percent of non-effective tiller hill^{-1} of Boro rice. At 150 DAT (at harvest) BRRI dhan63 (V_2) and BRRI dhan28 (V_1) produced similar number of effective tiller hill^{-1} both mathematically and statistically (Fig 8). This data showed non-significant result at 26df at 5% level of significance (Appendix XXII).

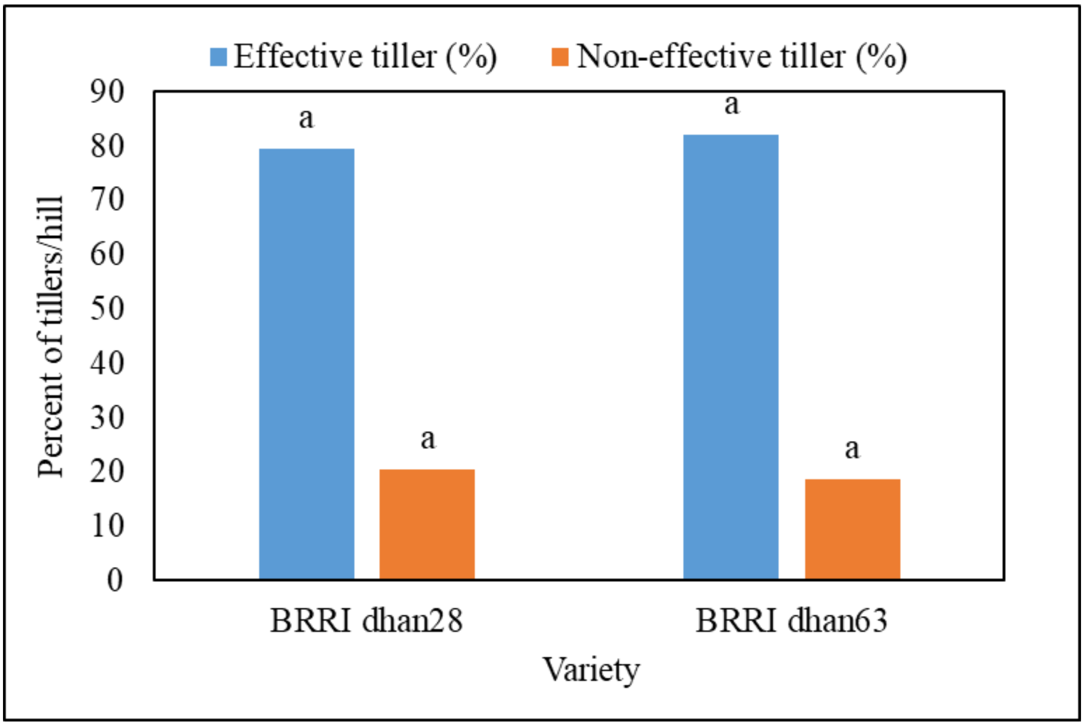

Figure 8: Varietal effect on percent of effective tiller number hill^{-1}, percent of non-effective tiller number hill^{-1} of Boro rice

For 150DAT (percent of effective tiller hill^{-1}), LSD $_{(5\%)}$ = 4.25, CV (%) = 8.30%; For 150DAT (percent of non-effective tiller hill^{-1}), LSD $_{(5\%)}$ = 4.19, CV (%) = 33.75%;

4.2.1.2 Effects of SNP2 and Carbendazim of total tiller number hill^{-1}, percent of effective tiller hill^{-1}, percent of non-effective tiller hill^{-1} of Boro rice

The line graph shows the effect of SNP2 and Carbendazim on total tiller number hill^{-1} of Boro rice at different days after transplanting. At 25 DAT, T_2 showed the highest value, it was statistically similar with T_0, T_5, T_6 and T_3 as well as the lowest total tiller number hill^{-1} was found in T_4 but it was statistically similar with T_1 and T_5; At 40 DAT, Results revealed T_0 showed the highest value and it was statistically similar with T_6, T_3 and T_2 as well as the lowest value was in T_4 and it was statistically similar with T_1 and T_5. At 55 DAT, T_3 showed the best result and it was statistically similar with T_5, T_1 and T_0 as well as T_6 had the lowest value and it was statistically similar with T_2 and T_4, At 70 DAT, T_5 showed the best result and it was statistically similar with T_3, T_1, T_4 and T_0; T_2 showed the lowest result and it was statistically similar with T_6 and T_4, At 150 DAT (at harvest) the total tiller number hill^{-1} showed T_5 showed the best result and it was statistically similar with T_3, T_1, T_4 and T_0; T_2 showed the lowest result and it was statistically similar with T_6 and T_4, (Fig 9). Here the total tiller hill^{-1} production of T_5 would be lowest at 25 DAT to 40 DAT but after that from 55 DAT the tiller growth started to increase quickly and up to harvest it produced the highest total tiller hill^{-1}. At 25 DAT, T_2 produced the highest number of total tiller hill^{-1} but then the value started to reduce and at last this value showed the lowest result. The all days after transplanting data had non-significant difference at 26df at 5% level of significance (Appendix XVI to XX).

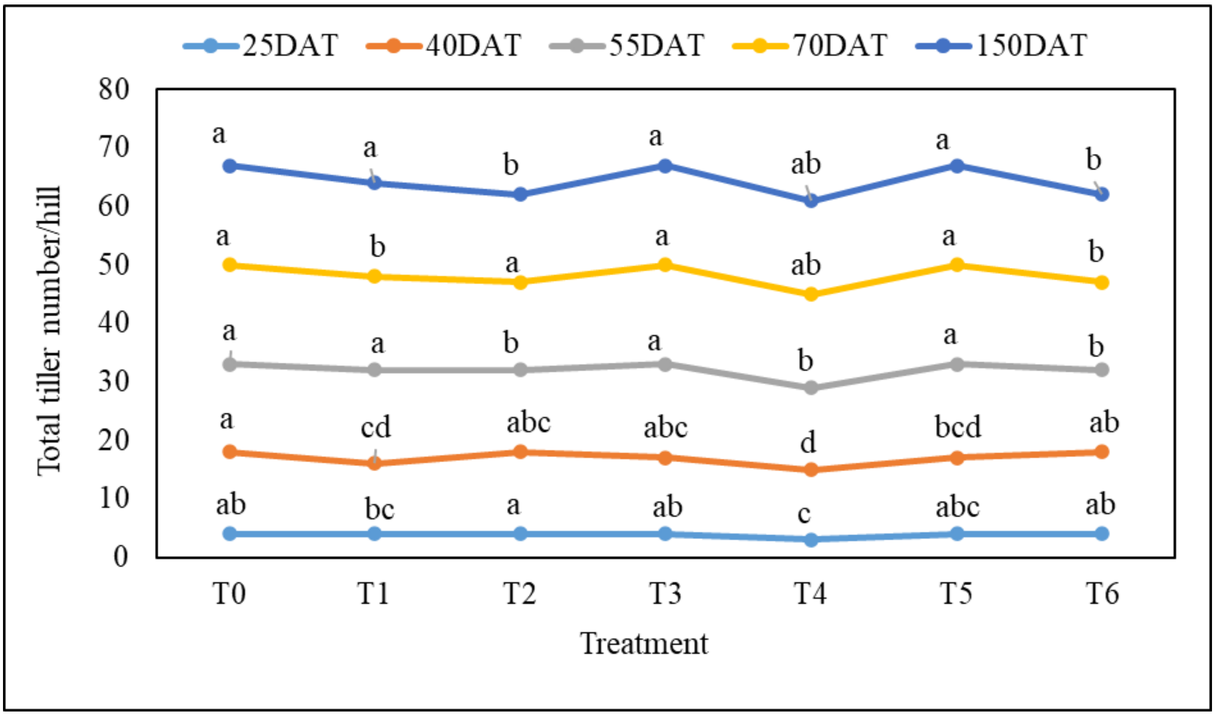

Figure 9: Effects of SNP2 and Carbendazim on total tiller number hill^{-1} of Boro rice at different days after transplanting

T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2; For 25DAT, LSD $_{(5\%)}$ = 0.65, CV (%) = 14.33% ; For 40DAT, LSD $_{(5\%)}$ = 1.26, CV (%) = 8.16% ; For 55DAT, LSD $_{(5\%)}$ =1.05, CV (%) = 5.92% ; For 70DAT, LSD $_{(5\%)}$ = 1.14, CV (%) = 6.03% ; For 150DAT, LSD $_{(5\%)}$ = 1.14, CV (%) = 6.03%

The bar graph shows the effect of SNP2 and Carbendazim on percent of effective tiller hill^{-1} of Boro rice. At 150 DAT (at harvest), T_5 showed the highest value, it was statistically similar with T_1 and the lowest percent of effective tiller hill^{-1} was found in T_3, but it was statistically similar with T_2, T_4 and T_6; (Fig 10). T_5 showed the highest value at total tiller number hill^{-1} and effective tiller number hill^{-1}, so the yield can be enhanced by this treatment. Zhang et al., (2021), found ZnO NPs application presented higher rice yield with more panicle number (4.83–13.14%), so it can be said the percent of effective tiller hill^{-1} also increase for that one.The data had non-significant difference at 26df at 5% level of significance (Appendix

XXI). The bar graph also shows the effect of SNP2 and Carbendazim on percent of non-effective tiller hill^{-1} of Boro rice. At 150 DAT (at harvest), T_3 showed the highest value, it was statistically similar with T_4, $T_2$and T_6 and the lowest non-effective tiller hill^{-1} was found in T_5 but it was statistically similar with T_1; T_5 showed the lowest value for this parameter (Fig 10), so most probably it would be the best treatment for grain production because it also showed the greatest result in previous two yield enhancing parameter. The data had non-significant difference at 26df at 5% level of significance (Appendix XXII).

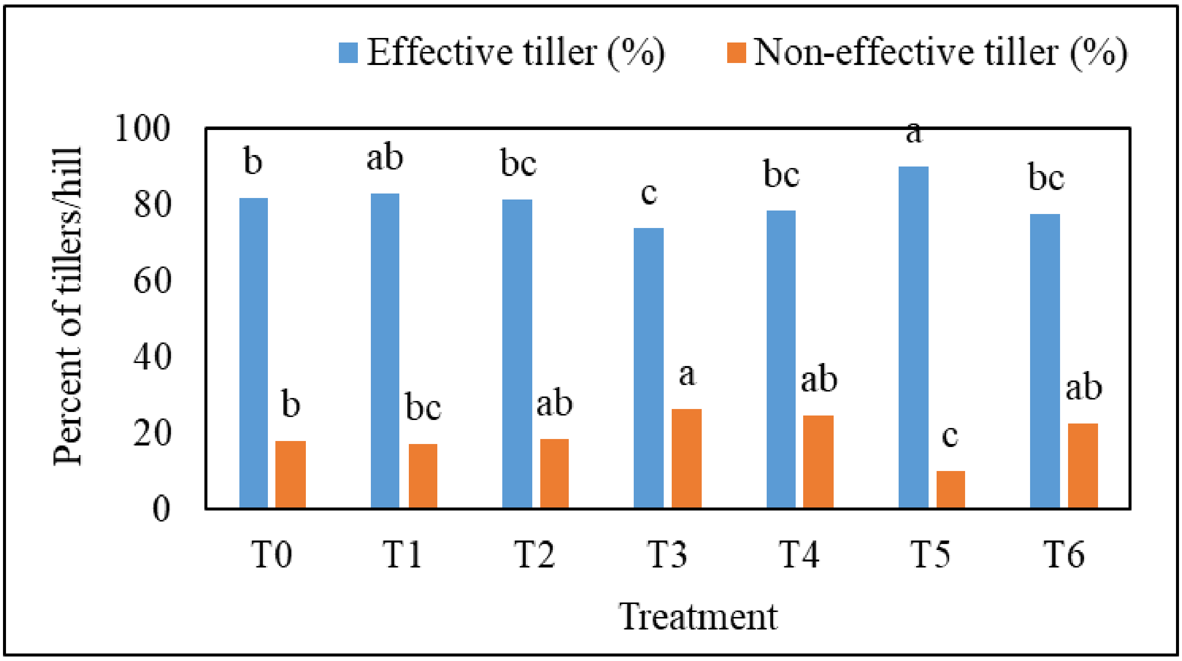

Figure 10: Effects of SNP2 and Carbendazim on effective tiller number hill^{-1} and non-effective tiller number hill^{-1} of Boro rice

T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2; For 150DAT (percent of effective tiller hill^{-1}), LSD $_{(5\%)}$ = 7.96, CV (%) = 8.30% ; For 150DAT (percent of non-effective tiller hill^{-1}), LSD$_{(5\%)}$ = 7.84, CV(%) = 33.75%;

4.2.1.3 Combined effect of treatments on total tiller number hill^{-1}, percent of effective tiller hill^{-1}, percent of non-effective tiller hill^{-1} of Boro rice

The line graph demonstrates the combined effect of treatments on total tiller number hill^{-1} of Boro rice at different days after transplanting. The data had no significant difference at 26df at 5% level of significance (Appendix XVI to XX). At 25 DAT, V_2T_2 showed the best result and it was statistically similar with V_1T_6, V_1T_3, V_2T_0, V_1T_2, V_1T_0 and V_2T_5 as well as V_2T_4 revealed the lowest result, it was statistically similar with V_1T_4, V_1T_1, V_2T_6, V_2T_1, V_1T_5, V_2T_3, V_2T_0, V_1T_2 and V_1T_0; At 40 DAT, V_2T_0 showed the highest result, it was statistically similar with

V_1T_0, V_1T_2, V_2T_1, V_2T_3, V_2T_6, V_1T_3, V_1T_5 and V_1T_6. The lowest result was found in V_1T_1, it was statistically similar with V_2T_5, V_1T_4 and V_2T_4; At 55 DAT, V_1T_1 showed the highest result and it was statistically similar with V_1T_3, V_2T_5, V_2T_3, V_1T_0, V_1T_2 V_2T_0, V_2T_1, V_2T_4 and V_1T_5 as well as the lowest value was found in V_2T_2, it was similar with V_1T_4, V_2T_6 and V_1T_6 statistically; At 70 DAT, V_1T_5 revealed the highest result and V_1T_3, V_2T_3, V_1T_0, V_2T_4, V_2T_5, V_1T_2, V_1T_4, V_2T_1 and V_2T_0 were statistically similar as well as V_2T_2 showed the lowest result and it was statistically similar with V_1T_6, V_1T_4, V_2T_6 and V_2T_1; At 150 DAT (at harvest), V_1T_5 revealed the highest result and V_1T_3, V_2T_3, V_1T_0, V_2T_4, V_2T_5, V_1T_2, V_1T_4, V_2T_1 and V_2T_0 were statistically similar as well as V_2T_2 showed the lowest result and it was statistically similar with V_1T_6, V_1T_4, V_2T_6 and V_2T_1; Here, V_1T_5 showed the best result but it revealed the lowest result similarity at 25 DAT, then it started to increase and showed similar result with the highest value and at 70 DAT it gained the highest position that means it produced the highest number of total tiller number hill^{-1}, on the other hand, V_2T_2 showed the highest value at 25 DAT, then it reduced and at harvest, it showed the lowest value not only statistically but also mathematically (Fig 11).

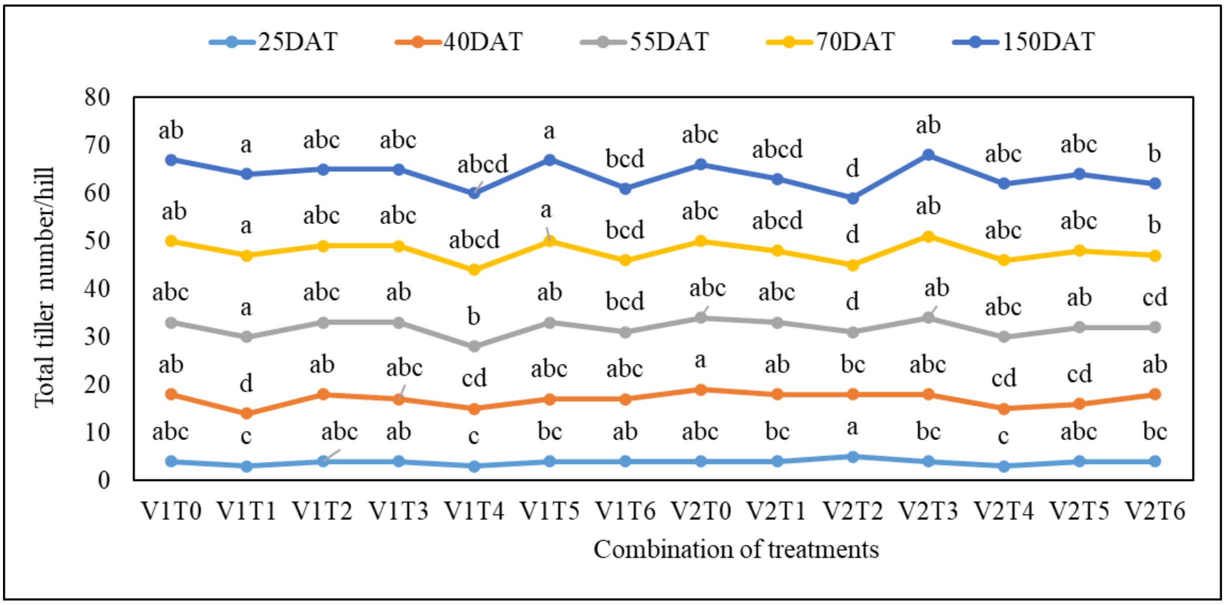

Figure 11: Combined effect of treatments on total tiller number hill^{-1} of Boro rice at different days after transplanting

V_1 = BRRI dhan28; V_2 = BRRI dhan63; T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2. For 25DAT, LSD $_{(5\%)}$ = 0.92, CV (%) = 14.33%; For 40DAT, LSD $_{(5\%)}$ = 1.79, CV (%) = 8.16%; For 55DAT, LSD $_{(5\%)}$ = 1.48, CV (%) = 5.92%; For 70DAT, LSD $_{(5\%)}$ = 1.62, CV (%) = 6.03%; For 150DAT, LSD $_{(5\%)}$ = 1.62, CV (%) = 6.03%;

The line graph demonstrates the combined effect of treatments on percent of effective tiller hill^{-1} of Boro rice. The data had no significant difference at 26df at 5% level of significance (Appendix XXI). At 150DAT (at harvest), V_2T_5 showed the best result and it was statistically similar with V_1T_5, V_2T_2, V_2T_6, V_2T_1, V_1T_1, V_1T_3, V_1T_2 and V_2T_0 as well as V_2T_3 revealed the lowest result, it was statistically similar with V_1T_6 and V_1T_4 (Fig 12). Here, V_1T_5 showed the highest value in previous said parameter but V_2T_5 was statistically similar with it and in this parameter V_2T_5 showed the highest value. As the percent of effective tiller hill^{-1} is the highest in V_2T_5, it may be more productive than V_1T_5. The line graph also demonstrates the combined effect of treatments on percent of non-effective tiller number hill^{-1} of Boro rice. The data had no significant difference at 26df at 5% level of significance (Appendix XXII). At 150 DAT (at harvest), V_2T_3 showed the best result and it was statistically similar with V_1T_6, V_1T_4 and V_2T_4, as well as V_2T_5 revealed the lowest result, it was statistically similar with V_1T_5, V_2T_6, V_2T_0, V_2T_1, V_1T_1, V_2T_2, V_1T_3 and V_1T_2 (Fig 12). Though V_1T_5 was similar with V_2T_5, but it showed the higher percent of non-effective tiller number hill^{-1} result than V_2T_5 mathematically and V_2T_5 was also the greatest position in percent of effective tiller hill^{-1}, it can be said V_2T_5 is the best one for these parameters. Grain yield can be increased through the combination of V_2T_5.

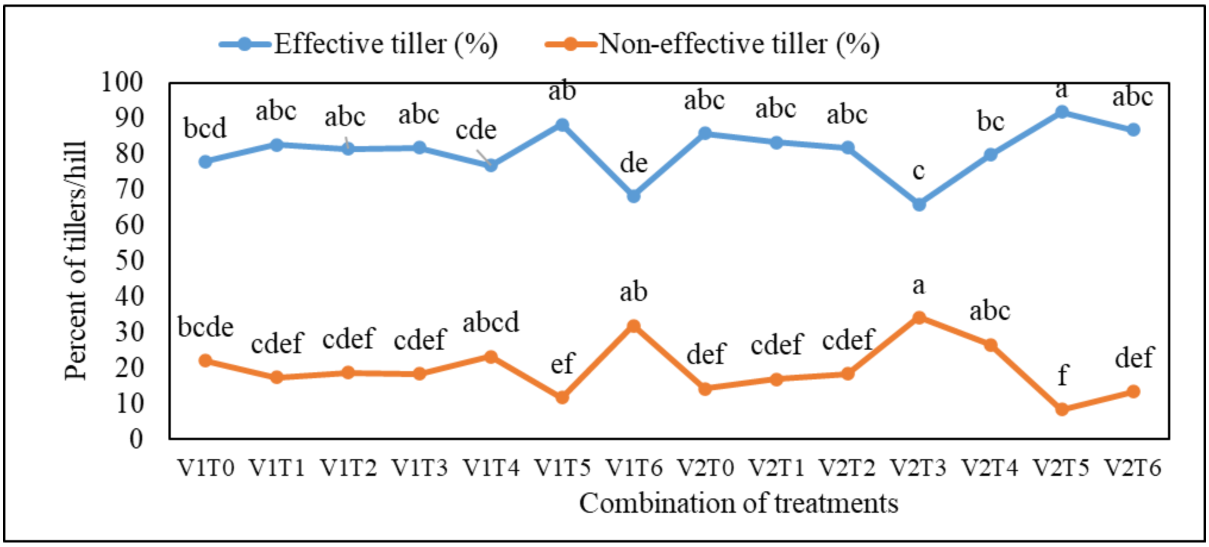

Figure 12: Combined effect of treatments on percent of effective tiller number hill^{-1} and non- effective tiller number hill^{-1} of Boro rice

V_1 = BRRI dhan28; V_2 = BRRI dhan63; T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2 ; For 150DAT (percent of effective tiller hill^{-1}), LSD $_{(5\%)}$ = 11.27, CV (%) = 8.30% ; For 150DAT (percent of non-effective tiller hill^{-1}), LSD $_{(5\%)}$ = 11.08, CV (%) = 33.75%;

4.2.2 Filled grains panicle^{-1}, unfilled grains panicle^{-1}and 1000-seed weight (g) on Boro rice

4.2.2.1 Varietal effect on filled grains panicle^{-1}, unfilled grains panicle^{-1} and 1000-seed weight (g) on Boro rice

The table 1 represents the varietal effect on filled grains panicle^{-1}, unfilled grains panicle^{-1}, 1000-seed weight (g) of Boro rice. At 150 DAT (at harvest) BRRI dhan63 (V_2) was similar BRRI dhan28 (V_1) in respect of filled grains panicle^{-1}, V_1 showed higher result than V_2 in respect of unfilled grains panicle^{-1} and 1000 seed weight (g) statistically. Though both varieties showed similar number of filled grains panicle^{-1}, V_2 produced lower number of unfilled grains panicle^{-1} than V_1, so V_2 could give more yield than V_1 but V_1 gave higher value in 1000-seed weight (g), it also could give some effect on yield. The filled grains panicle^{-1} showed non-significant and significant result in unfilled grains panicle^{-1} and 1000-seed weight (g) at 26df at 5% level of significance (Appendix XXIII to XXV).

Table 1: Varietal effect on filled grains panicle^{-1}, unfilled grains panicle^{-1}and 1000-seed weight (g) on Boro rice

Variety	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-seed weight (g)
V_1	64 a	25 a	23.03 a
V_2	65 a	24 b	22.04 b
LSD $_{(5\%)}$	1.59	0.60	0.06
CV (%)	3.89 %	3.88%	0.47%

V_1 = BRRI dhan28, V_2 = BRRI dhan63

4.2.2.2 Effects of SNP2 and Carbendazim on filled grains panicle^{-1}, unfilled grains panicle^{-1} and 1000-seed weight (g) on Boro rice

The table (table 2) represents the effect of SNP2 and Carbendazim on filled grains panicle^{-1}, unfilled grains panicle^{-1} and 1000-seed weight (g) of Boro rice. For filled grain panicle^{-1}, at 150DAT (at harvest), T_5 showed the highest value, it was statistically similar with T_1 and T_2 as well as the lowest one was found in T_0 but it was statistically similar with T_6 and T_3; For unfilled grains panicle^{-1}, at 150 DAT (at harvest), T_0 showed the highest value as well as the lowest one was found in T_5 but it was statistically similar with T_4; For 1000-seed weight (g), at 150DAT (at harvest), treatments are statistically similar. As T_5 showed highest filled grains panicle^{-1} and lowest unfilled grains panicle^{-1} is compared with T_0, it may give the highest yield.

The data had non-significant difference at 26df at 5% level of significance (Appendix XXIII to XXV). Zhang et al., (2021) ZnO NPs application presented higher rice yield with more filled grain rate (0.28–2.36%), maybe it is responsible for highest filled grains panicle^{-1} in present research.

Table 2: Effects of SNP2 and Carbendazim on filled grains panicle^{-1}, unfilled grains panicle^{-1} and 1000-seed weight (g) on Boro rice

Treatment	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-seed weight (g)
T_0	60 c	28 a	22.51 a
T_1	68 a	26 b	22.53 a
T_2	67 a	24 cd	22.53 a
T_3	63 bc	24 cd	22.55 a
T_4	64 b	23 de	22.54 a
T_5	70 a	22 e	22.56 a
T_6	62 bc	24 c	22.53 a
LSD $_{(5\%)}$	2.98	1.12	0.12
CV (%)	3.89 %	3.88%	0.47%

T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2;

4.2.2.3 Combined effect of treatments on filled grains panicle^{-1}, unfilled grains panicle^{-1} and 1000-seed weight (g) on Boro rice

The table (table 3) demonstrates the combined effect of treatments on filled grains panicle^{-1}, unfilled grains panicle^{-1} and 1000-seed weight (g) of Boro rice. For filled grains panicle^{-1}, at 150 DAT (at harvest), V_2T_5 showed the best result and it was statistically similar with V_1T_1, V_1T_2, V_1T_5 and V_2T_1 as well as V_1T_0 revealed the lowest result, it was statistically similar with V_1T_6 , V_1T_4 and V_2T_0; For unfilled grains panicle^{-1}, at 150 DAT (at harvest), V_1T_0 showed the best result as well as V_2T_5 revealed the lowest result, it was statistically similar with V_1T_5 , V_1T_4, V_2T_3, V_1T_2 and V_2T_4; For 1000-seed weight (g), at 150 DAT (at harvest), V_1T_5 showed the best result and V_1T_3, V_1T_1, V_1T_4, V_1T_2, V_1T_5, V_1T_0 are statistically similar as well as V_2T_0 revealed the lowest result, it was statistically similar with V_2T_2 , V_2T_1, V_2T_3, V_2T and V_2T_4;

As V_2T_5 showed the highest value of filled grains panicle^{-1} and lowest value of unfilled grains panicle^{-1} as well as V_1T_0 showed the opposite result of V_2T_5; So grain yield could be enhanced through V_2T_5, it means that treatment is better comparing with V_1T_0 and V_2T_0. The data showed non-significant difference at 26df at 5% level of significance (Appendix XXIII to XXV).

Table 3: Combined effect of treatments on filled grains panicle^{-1}, unfilled grains panicle^{-1} and 1000-seed weight (g) on Boro rice

Combination	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-seed weight (g)
V_1T_0	58 f	29 a	23.00 a
V_1T_1	69 ab	25 cd	23.03 a
V_1T_2	69 ab	23 fgh	23.02 a
V_1T_3	63 cde	25 cde	23.05 a
V_1T_4	62 def	22 gh	23.03 a
V_1T_5	69 ab	23 fgh	23.06 a
V_1T_6	60 ef	25 cde	23.02 a
V_2T_0	62 cdef	27 b	22.02 c
V_2T_1	66 abc	26 bc	22.03 c
V_2T_2	65 bcd	24 def	22.03 c
V_2T_3	63 cde	23 gh	22.05 c
V_2T_4	65 bcd	23 fgh	22.05 c
V_2T_5	70 a	22 h	22.06 bc
V_2T_6	63 cde	23 efg	22.03 c
LSD $_{(5\%)}$	4.22	1.58	0.17
CV (%)	3.89 %	3.88%	0.47%

V_1 = BRRI dhan28, V_2 = BRRI dhan63, T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2;

4.2.3 Grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice

4.2.3.1 Varietal effect on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice

The table (table 4) represents the varietal effect on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice. The data showed significant result without harvest index (%) at 26df at 5% level of significance (Appendix XXVI to XXIX). At 150 DAT (at harvest) BRRI dhan63 (V_2) showed higher result than BRRI dhan28 (V_1) in respect of table included parameters. V_2 had the highest dry matter accumulation rate (g) and lower unfilled grain panicle^{-1} and the potential yield of V_2 is greater than V_1, that's why the grain yield (t ha^{-1}) of V_2 was better than V_1.

Table 4: Varietal effect on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice

Variety	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	4.95 b	4.67 b	9.63 b	51.49 a
V_2	6.11 a	5.71 a	11.82 a	51.72 a
LSD $_{(5\%)}$	0.02	0.15	0.15	0.54
CV (%)	0.66%	4.68%	2.34%	2.29%

Here, V_1 = BRRI dhan28, V_2 = BRRI dhan63

4.2.3.2 Effects of SNP2 and Carbendazim on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice

The table (table 5) represents the effect of SNP2 and Carbendazim on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice. For grain yield (t ha^{-1}), at 150 DAT (at harvest), T_5 showed the highest value, as well as the lowest one was found in T_1 both mathematically and statistically; For straw yield (t ha^{-1}), at 150 DAT (at harvest), T_3 showed the highest value and T_5 and T_2 as well as the lowest one was found in T_1 but it was statistically similar with T_0 and T_6; For biological yield (t ha^{-1}), T_5 showed the greatest value and it was statistically similar with T_3 and T_2 as well as the lowest one was T_1 and it is statistically similar with T_0 and T_6. For harvest index (%), T_4 showed the greatest value and it was statistically similar with T_6, T_0, T_1, T_2 and T_5 and T3 was the lowest and it was statistically similar with T_5, T_2, T_0 and T_1. The highest grain yield(t/ha) was shown in T_5 because T_5 gave the highest value in total tiller hill^{-1}, effective tiller hill^{-1} and filled grain panicle^{-1} and the lowest value in non-effective tillers hill^{-1} and unfilled grain hill^{-1}. The data had non-significant difference at 26df at 5% level of significance (Appendix XXVI to XXIX). Poornima & Rv, (2019), showed that grain yield was 9.5% higher in 500 ppm of Nano foliar spray as compare with 1000 ppm of Bulk foliar spray. Liu et al., (2019), showed nCuO has significant effect in panicle number, total grain weight, average grain weight and several other panicle parameters. Gogoi et al.,(2022) showed that Carbendazim 50WP provided 62.02% increased yield over control. That means, most probably combined effect of nCuO, nZnO and Carbendazim can increase the yield and yield enhancing components or rice in this experiment.

Table 5: Effects of SNP2 and Carbendazim on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_0	5.38 d	5.03 cd	10.41 d	51.62 ab
T_1	5.15 e	4.80 d	9.96 e	51.66 ab
T_2	5.66 b	5.34 ab	11.00 ab	51.43 ab
T_3	5.66 b	5.52 a	11.19 a	50.60 b
T_4	5.62 b	5.15 bc	10.78 bc	52.35 a
T_5	5.74 a	5.45 a	11.20 a	51.25 ab
T_6	5.49 c	5.05 cd	10.55 cd	52.30 a
LSD $_{(5\%)}$	0.04	0.28	0.29	1.40
CV (%)	0.66%	4.68%	2.34%	2.29%

T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2;

4.2.3.3 Combined effect of treatments on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice

The table (table 6) demonstrates the combined effect of treatments on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice. For grain yield (t ha^{-1}), at 150 DAT (at harvest), V_2T_5 showed the best result as well as V_1T_1 revealed the lowest result; For straw yield (t ha^{-1}), at 150 DAT (at harvest), V_1T_3 showed the best result it was statistically similar with V_2T_4, V_2T_5, V_2T_6 and V_2T_2 as well as V_1T_6 revealed the lowest result, it was statistically similar with V_1T_1 and V_1T_4; For biological yield (t ha^{-1}), at 150 DAT (at harvest), V_2T_5 showed the best result and V_2T_3, V_2T_4 and V_2T_2 were statistically similar as well as V_1T_1 revealed the lowest result both mathematically and statistically; For harvest index (%), at 150 DAT (at harvest), V_1T_6 showed the best result and V_1T_4, V_2T_1 ,V_2T_0, V_2T_5 and V_2T_2 were statistically similar as well as V_1T_3 revealed the lowest result and it was statistically similar with V_1T_1, V_1T_2, V_1T_5, V_2T_3, V_1T_0, V_2T_6, V_2T_4, V_2T_5 and V_2T_2; The highest grain yield (t ha^{-1}) was found in V_2T_5 in case of finding the highest result similarity in total tiller $hill^{-1}$ and effective tiller $hill^{-1}$ and the highest in filled grain $panicle^{-1}$ and the lowest result in non-effective tiller $hill^{-1}$ and unfilled grain $panicle^{-1}$. The data showed non-significant difference at 26df at 5% level of significance (Appendix XXVI to XXIX).

Table 6: Combined effect of treatments on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice

Combination	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1T_0	5.00 g	4.84 c	9.84 d	50.77 bc
V_1T_1	4.43 h	4.31 d	8.75 f	50.68 bc
V_1T_2	5.10 f	4.95 bc	10.05 d	50.72 bc
V_1T_3	5.09 f	5.00 bc	10.10 d	50.44 c
V_1T_4	4.96 g	4.34 d	9.30 e	53.42 a
V_1T_5	5.14 f	4.99 bc	10.13 d	50.76 bc
V_1T_6	4.96 g	4.29 d	9.25 e	53.64 a
V_2T_0	5.76 e	5.22 bc	10.98 c	52.48 ab
V_2T_1	5.87 d	5.29 b	11.17 c	52.64 ab
V_2T_2	6.22 b	5.73 a	11.95 ab	52.14 abc
V_2T_3	6.23 b	6.04 a	12.27 a	50.77 bc
V_2T_4	6.28 b	5.97 a	12.25 ab	51.28 bc
V_2T_5	6.35 a	5.92 a	12.27 a	51.74 abc
V_2T_6	6.03 c	5.81 a	11.85 b	50.96 bc
LSD $_{(5\%)}$	0.06	0.40	0.42	1.98
CV (%)	0.66%	4.68%	2.34%	2.29%

V_1 = BRRI dhan28, V_2 = BRRI dhan63, T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2;

4.3 Combination of the effects of different treatments on all parameters through matrix ranking and scoring

Table 7: Matrix Ranking and Scoring for all parameters for identifying best variety

Scale		Parameter	Variety			
Rank	Score		BRRI dhan28 (V_1)		BRRI dhan63 (V_2)	
1	1		Rank	Score	Rank	Score
0	0	Plant height (cm)	1	1	0	0
		Total tiller number hill^{-1}	1	1	0	0
		Percent effective tiller hill^{-1}	0	0	1	1
		Filled grain Panicle^{-1}	0	0	1	1
		Unfilled grain panicle^{-1}	0	0	1	1
		1000-seed wt (g)	1	1	0	0
		Dry matter (g)	0	0	1	1
		Straw yield (t ha^{-1})	0	0	1	1
		Grain yield (t ha^{-1})	0	0	1	1
		Biological yield (t ha^{-1})	0	0	1	1
		Harvest Index (%)	0	0	1	1
		Total		3		8

Matrix ranking and scoring was done for identifying best one mathematically. Here, rank 1 was used for the best variety and 0 was for the lowest one. V_2 provided the best result comparing with V_1 because it gained the largest position for all parameters except plant height (cm), total tiller hill^{-1} and 1000-seed weight (g) (table 7). From statistical analysis, the same result had found. Therefore, it can be said that V_2 is the best one.

Table 8: Matrix Ranking and Scoring for all parameters for identifying best treatment

Scale			Treatment														
Rank (R)	Score (S)		Parameter	T_0		T_1		T_2		T_3		T_4		T_5		T_6	
1	10			R	S	R	S	R	S	R	S	R	S	R	S	R	S
2	9		Plant height (cm)	3	8	5	6	2	9	4	7	6	5	1	10	7	4
3	8		Total tiller number hill^{-1}	2	9	3	8	5	6	2	9	4	7	1	10	5	6
4	7		Percent of effective tiller hill^{-1}	3	8	2	9	4	7	7	4	5	6	1	10	6	5
5	6		Filled grain panicle^{-1}	7	4	2	9	3	8	5	6	4	7	1	10	6	5
6	5		Unfilled grain panicle^{-1}	7	4	6	5	3	8	4	7	2	9	1	10	5	6
7	4		1000-seed wt (g)	7	4	4	7	5	6	2	9	3	8	1	10	6	5
			Dry matter (g)	6	5	7	4	3	8	1	10	5	6	4	7	2	9
			Straw yield (t ha^{-1})	6	5	7	4	3	8	1	10	4	7	2	9	5	6
			Grain yield (t ha^{-1})	6	5	7	4	3	8	2	9	4	7	1	10	5	6
			Biological yield (t ha^{-1})	6	5	7	4	3	8	2	9	4	7	1	10	5	6
			Harvest Index (%)	4	7	3	8	5	6	7	4	1	10	6	5	2	9
			Total	64		68		82		92		79		101		67	

T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2;

Matrix ranking and scoring was done for the identification of mathematically best treatment. Here, rank-1 indicates the best treatment and 7 indicates the lowest treatment. T_5 showed the best result for all parameters where T_0 showed the lowest treatment in this aspect. T_5 showed the best result in all parameters without dry matter (g), straw yield (t ha^{-1}), harvest index (%) (table 8). Carbendazim was better than control but not better than 1ml L^{-1} SNP2 and 2ml L^{-1} SNP2. Treatment showed better result in Nanoproduct up to 2ml L^{-1} SNP2 but 3ml L^{-1} SNP2 showed lower result than them; however, 2ml L^{-1} SNP2 showed lower result than 3ml L^{-1} SNP2 when it mixed with Carbendazim but it was better than only Carbendazim and Calculating scores, it was better than control (table 9). So T_5 was the best one not only statistically but also mathematically.

Table 9: Matrix Ranking and Scoring for all parameters for identifying best combination

Scale	
Rank (R)	Score (S)
1	14
2	13
3	12
4	11
5	10
6	9
7	8
8	7
9	6
10	5
11	4
12	3
13	2
14	1

Combination														
Parameter	T_0		T_1		T_2		T_3		T_4		T_5		T_6	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
Plant height (cm)	11	4	10	2	12	7	13	1	9	5	14	6	8	3
Total tiller number hill^{-1}	13	12	14	10	11	7	12	13	10	12	14	12	9	8
Percent of effective tiller hill^{-1}	4	11	9	10	6	8	7	11	3	5	13	14	2	12
Filled grain panicle^{-1}	5	8	13	12	13	11	10	9	7	11	13	14	6	10
Unfilled grain panicle^{-1}	1	2	4	3	9	7	5	11	10	9	9	14	11	8
1000-seed wt (g)	9	4	12	5	11	5	13	7	12	7	14	8	10	6
Dry matter (g)	3	4	1	2	8	12	11	13	5	10	7	9	6	14
Straw yield (t ha^{-1})	4	8	2	9	5	10	7	14	3	13	6	12	1	11
Grain yield (t ha^{-1})	4	8	1	9	6	11	5	12	3	13	7	14	2	10
Biological yield (t ha^{-1})	5	9	2	10	6	12	7	14	4	13	8	14	3	11
Harvest Index (%)	6	11	2	12	3	10	1	5	13	8	4	9	14	7
Total (score)	V_1=65 V_2=77		V_1=70 V_2=84		V_1=90 V_2=100		V_1=91 V_2=110		V_1=79 V_2=106		V_1=109 V_2=126		V_1=72 V_2=100	

V_1 = BRRI dhan28, V_2 = BRRI dhan63, T_0 = Control, T_1 = Carbendazim 2g L^{-1}, T_2 = 1.0 ml L^{-1} SNP2, T_3 = 2.0 ml L^{-1} SNP2, T_4 = 3.0 ml L^{-1} SNP2, T_5 = Carbendazim, 2g L^{-1} + 1.0 ml L^{-1} SNP2, T_6 = Carbendazim, 2g L^{-1} + 2.0 ml L^{-1} SNP2;

For the identification of the best treatment matrix ranking and scoring had done. Here, 1 rank indicates the best combination and 14 rank indicates the lowest one. V_2T_5 gave the best result mathematically in respect of all combinations except plant height (cm), total tiller number $hill^{-1}$, 1000-seed weight (g), dry matter (g), straw yield (t ha^{-1}), harvest index (%). T_5 was the best and T_0 was the lowest for both varieties. (Table 9). So T_5 was the best one not only statistically but also mathematically.

CHAPTER V

SUMMARY AND CONCLUSION

The research work was done at agronomy field, Sher-e-Bangla Agricultural University, Dhaka during the period from December to January (2019-2020) to find out the effect of nanoproduct and commercial fungicide on growth, yield and yield components of Boro rice. The experiment was carried out in a Randomized Complete Block Design (RCBD) with three replications. The total plot number was 42 and size of the plot was $4m^2$. Two rice varieties (BRRI dhan28 and BRRI dhan63) and 7 treatments [T_0 – controlled (only water); T_1 – Carbendazim @ 2g L^{-1}; T_2 –SNP2 @ 1.0 ml L^{-1}; T_3 – SNP2 @ 2.0 ml L^{-1}; T_4 –SNP2 @ 3.0 ml L^{-1}; T_5 – Carbendazim @ 2g L^{-1}+ SNP2 @ 1.0 ml L^{-1}; T_6 – Carbendazim @ 2g L^{-1}+ SNP2 @ 2.0 ml L^{-1}] were included in the experiment. At 25 DAT, 40 DAT, 55 DAT and 70DAT, we collected plant height (cm), and dry matter (g), we also collected these data at the time of harvesting. Yield and yield components data were collected at the time of harvesting and after harvesting. Yield components data were total tiller number hill^{-1}, percent of effective tiller hill^{-1}, percent of non-effective tiller hill^{-1}, filled grain panicle^{-1}, unfilled grain panicle^{-1}and 1000-grain weight (g). Yield data were grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}), and harvest index (%). We used Balanced ANOVA at CROPSTAT software for data analysis and LSD test were done for mean separation at 5% level of significance. Results revealed that BRRI dhan63 showed higher result than BRRI dhan28 in respect of grain yield (6.11 t ha^{-1}) because BRRI dhan63 had the highest dry matter accumulation (g) and lower unfilled grain panicle^{-1} and the potential yield of it is greater than BRRI dhan28. The highest grain yield (5.74 t ha^{-1}) was shown in T_5 because T_5 gave the highest value in total tiller hill^{-1}, effective tiller hill^{-1} and filled grain panicle^{-1} and the lowest value in non-effective tillers hill^{-1} and unfilled grain hill^{-1}. The highest grain yield (6.35 t ha^{-1}) was found in T_5 when combined with BRRI dhan63 in case of finding it as the highest result similarity in total tiller hill^{-1} and effective tiller hill^{-1} and the highest in filled grain panicle^{-1} and the lowest result in non-effective tiller hill^{-1} and unfilled grain panicle^{-1}. Result also revealed T_5 was comparatively better than T_0 both treatment and combination. Carbendazim mainly acts as fungicide but in our study when Carbendazim mixed with SNP2 @ 1ml L^{-1}, it acted as grain yield (t ha^{-1}) promoter. Result also revealed that the use of the Nanoproduct boosted up yield in varieties comparing to the control treatment (T_0) under study.

From this experiment, the result can be concluded that as variety BRRI dhan63 was the best and mixture of Carbendazim and SNP2 @ 1ml L^{-1} was the best and as a combination BRRI dhan63 with mixture of Carbendazim and SNP2 @ 1ml L^{-1} was the best. Biomolecular experiment, mineral fortification and experiment with this best treatment with other growth hormones can be considered as recommendation. Therefore, it can be involved in further study.

References

Abdul-Hadi, B. D., Alao, S. E. L., Zarafi, A. B., and Kashina, B. D. (2021). Effect of Foliar Application of Zinc. *Nigerian J. Pl. Protec. 35: 35*(1), 22–31.

Adhikari, T., Kundu, S., Biswas, A. K., Kundu, S., Tarafdar, J. C., and Rao, A. S. (2012). Effect of Copper Oxide Nano Particle on Seed Germination of Selected Crops. *J. Agric. Sci. and Techn.*, 815–823.

Ahamed, M., Alhadlaq, H. A., Khan, M. A. M., Karuppiah, P., and Al-Dhabi, N. A. (2014). Synthesis, characterization, and antimicrobial activity of copper oxide nanoparticles. *J. Nanomaterials.*

Anitha, S. R., and Savitha, G. (2015). Research Article Carbendazim Induced Alterations in Morphological Responses , Chlorophyll , and Phenolic Contents of Rice Cultivars. *6*: 4978–4982.

Agriculture Statistics Wing, BBS, 2022

Baker, S., Volova, T., Prudnikova, S. V., Satish, S., and Prasad M.N., N. (2017). Nanoagroparticles emerging trends and future prospect in modern agriculture system. *Env. Toxico. and Pharmaco., 53*: 10–17.

Bala, R., Kalia, A., and Dhaliwal, S. S. (2019). Evaluation of Efficacy of ZnO Nanoparticles as Remedial Zinc Nanofertilizer for Rice. *J. Soil Sci. and Pl. Nutri.*, *19*(2): 379–389.

Bangladesh economic review, 2022-2023;

Bangladesh Bureau of Statistics (Issue May). (2019).

Bangladesh Rice Knowledge Bank, BRRI;

Bhowmik, P., and Biswas, P. (2022). Improving yield of rice by managing blast disease through On Farm Trial (OFT) in old alluvial zone of West Bengal. *J. Crop and Weed*, *18*(1): 151–159.

Boonyanitipong, P., Kositsup, B., Kumar, P., Baruah, S., and Dutta, J. (2011). Toxicity of ZnO and TiO_2 Nanoparticles on Germinating Rice Seed *Oryza sativa* L. *Intl. J. Biosci., Biochem. and Bioinf.*, *1*(4): 282–285.

Chaitra, S., and Anitha, S. R. (2016). Effect of carbendazim on seed germin. and biochem. changes of rice *(Oryza sativa).* Original Research Paper Commerce Biochem. Cultivar Dept. of Biochem. , SBRR Mahajana First Grade College , Dept. of Biochem. , SBRR Mahajana F. *7*: 18–19.

Da Costa, M. V. J., and Sharma, P. K. (2016). Effect of copper oxide nanoparticles on growth, morphology, photosynthesis, and antioxidant response in *Oryza sativa.* Photosynthetica, 54(1):110–119.

Effect of Nano-ZnO Particle Suspension on Growth of Mung *(Vigna radiata)* and Gram *(Cicer arietinum)* Seedlings Using Pl. Agar Method. (2011).

Elizabath, A., Bahadur, V., Misra, P., Mashi Prasad, V., Thomas, T., and Ambily Elizabath, C. (2017). Effect of different concentrations of iron oxide and zinc oxide nanoparticles on growth and yield of carrot (*Daucus carota* L.). *J. of Pharmacog. and Phytochem. JPP*, *6*(4): 1266–1269.

Ghidan, A. Y., Al-Antary, T. M., Salem, N. M., and Awwad, A. M. (2019). Facile Green Synthetic Route to the Zinc Oxide (ZnONPs) Nanoparticles: Effect on Green Peach Aphid and Antibacterial Activity. *J. Agric. Sci.*, *9*(2): 131.

H., R., H.B., N., and Patil, B. (2022). Appraise a seed Treatment of Carbendazim 50% WP against Sheath Blight Disease of Rice (*Oryza sativa* L.). *Ecolo., Env. and Conser.*, *28*(01s): 72–72.

H, U. (2017). Physiological impact of Zinc nanoparticle on germination of rice (*Oryza sativa* L) seed. *J. of Pl. Sci. and Phytopath.*, *1*(2): 062–070.

Jaiganesh, V. (2018). Integrated management of blast diseases in rice. *J. Biopest.*, *11*(2): 82–88.

Jamdagni, P., Rana, J. S., and Khatri, P. (2018). Comparative study of antifungal effect of green and chemically synthesised silver nanoparticles in combination with carbendazim, mancozeb, and thiram. *IET Nanobiotech.*, *12*(8): 1102–1107.

Jangid, B., Srinivas, A., Kumar, R. M., Ramprakash, Prasad, TNVKV, T., Kumar, K. A., Reddy, S. N., and Kumar, V. (2019). Influence of zinc oxide nanoparticles foliar application on zinc uptake of rice (*Oryza sativa* L.) under different establishment methods. *Intl. J. Chem. Stud.*, *7*(1): 257–261.

Javadimoghadam, A., Moghadam, A. L., E. D., (2015). Response of growth and yield of cucumber plants (*Cucumis sativus* L.) to different foliar applications of humic acid and bio-stimulators. *Australia J.of Basic and App.Sci.*, *6*(3): 630–637.

Kasana, R. C., Panwar, N. R., and Kaul, R. K. (2016). Copper Nanoparticles in Agriculture : Biological Synthesis and Antimicrobial Activity. 129–143.

Kumar, S., Kumar, V., Mishra, D. P., and . E. (2017). Evaluation of Efficacy of different Fungicides againstFalse Smutdisease in rice. *J. AgriSearch*, *4*(04): 273–275.

Lemraski, M. G., Normohamadi, G., Madani, H., Heidari, H., Abad, S., and Mobasser, H. R. (2017). Two Iranian Rice Cultivars ' Response to Nitrogen and Nano-Fertilizer. 591–603.

Li, J., Zhou, X., Zhang, C., Zhao, Y., Zhu, Y., Zhang, J., Bai, J., and Xiao, X. (2020). The Effects of Carbendazim on Acute Toxicity, Development, and Reproduction in Caenorhabditis elegans. *J. Food Quality*, *2020*.

Liu, Wang, W., Jiaqi, Ren, Y., Zhang, L., Xue, Y., Zhang, L., and He, J. (2019). Phytotoxicity Assessment of Copper Oxide Nanoparticles on the Germination, Early Seedling Growth, and Physiological Responses in *Oryza sativa* L. Bul. Env. Contamin. and Toxico., *104*(6): 770–777.

Mathivanan, N., and Prabavathy, V. R. (2007). Effect of carbendazim and mancozeb combinationon Alternaria leaf blight and seed yield in sunflower (*Helianthus annus* L.). *Archives Phytopath. and Pl. Protec.*, *40*(2): 90–96.

Muthukumar, A., Kanagarajan, R., and Udhayakumar, R. (2019). Evaluation of fungicide against sheath blight *(Rhizoctonia solani*) of Rice. *8*(3): 494–497.

Nair, P. M. G., and Chung, I. M. (2014). Chemosphere Physiological and molecular level effects of silver nanoparticles exposure in rice (*Oryza sativa* L .) seedlings. CHEMOSPHERE, *112*: 105–113.

Ogunyemi, S. O., Zhang, F., Abdallah, Y., Zhang, M., Wang, Y., Sun, G., Qiu, W., and Li, B. (2019). Biosynthesis and characterization of magnesium oxide and manganese dioxide nanoparticles using *Matricaria chamomilla* L . extract and its inhibitory effect on Acidovorax *oryzae strain RS-2*. *Artificial Cells, Nanomedicine, and Biotechnology*, *47*(1): 2230–2239.

Phogat, N., Khan, S. A., Shankar, S., Ansary, A. A., and Uddin, I. (2016). Fate of inorganic nanoparticles in agriculture. *Adv. Mat. Let.*, *7*(1): 3–12.

Poornima, R., and Rv, K. (2019). Effect of nano zinc oxide on growth , yield and grain zinc content of sorghum *(Sorghum bicolor)*. *8*(4): 727–731.

Prasad, T. N. V. K. V., Sudhakar, P., Sreenivasulu, Y., Latha, P., Munaswamy, V., Raja Reddy, K., Sreeprasad, T. S., Sajanlal, P. R., and Pradeep, T. (2012). Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. *J. Pl. Nutri.*, *35*(6): 905–927.

Program, P., and Division, A. A. (2020). A monthly publication of the USDA AMS, Livestock and Poultry Program, *Agric. Analyt. Div.*, 1–4.

Rajput, V. D., Minkina, T., Suskova, S., Mandzhieva, S., Tsitsuashvili, V., Chapligin, V., and Fedorenko, A. (2018). Effects of Copper Nanoparticles (CuO NPs) on Crop Plants: a Mini Review. *BioNanoSci.*, *8*(1): 36–42.

Ramadan, A. A. E., El-bassiouny, H. M. S., and Bakry, B. A. (2020). Growth , Yield and Biochemical Changes of Soybean Plant in Response to Iron and Magnesium Oxide Nanoparticles.

Rastogi, A., Tripathi, D. K., Yadav, S., Chauhan, D. K., Živčák, M., Ghorbanpour, M., El-Sheery, N. I., and Brestic, M. (2019). Application of silicon nanoparticles in agriculture. *3 Biotech*, *9*(3): 1–11.

Ren, G., Hu, D., Cheng, E. W. C., Vargas-Reus, M. A., Reip, P., and Allaker, R. P. (2008). Characterisation of copper oxide nanoparticles for antimicrobial applications. *Int. J. Antimicro. Agents*, *33*(6): 587–590.

Sabir, S., Arshad, M., and Chaudhari, S. K. (2014). Zinc oxide nanoparticles for revolutionizing agriculture: Synthesis and applications. *Sci. World J.*, *2014*.

Sharma, G., Soni, R., and Jasuja, N. D. (2017). Phytoassisted synthesis of magnesium oxide nanoparticles with *Swertia chirayaita* . *J. Taibah Univ. for Sci.*, *11*(3): 471–477.

Shi, J., Ye, J., Fang, H., Zhang, S., and Xu, C. (2018). Effects of copper oxide nanoparticles on paddy soil properties and components. *Nanomaterials*, *8*(10): 1–14.

Singh, A., Chandra, R., and Rattan Bhardwaj, N. (2015). Evaluation of Fungicides against *Rhizoctonia solani* Causal Agent Of Sheath Blight of Rice. *Intl. J. App. and Pure Sci. and Agri.*, *1*(8): 130–139.

Singh, S., Singh, N., Kumar, V., Datta, S., Wani, A. B., Singh, D., Singh, K., and Singh, J. (2016). Toxicity, monitoring and biodegradation of the fungicide carbendazim. *Env. Chem. Letters*, *14*(3): 317–329.

Srinivasan, R., Maity, A., Singh, K. K., Ghosh, P. K., Kumar, S., Srivastava, M. K., Radhakrishna, A., Srivastava, R., and Kumari, B. (2017). Influence of copper oxide and zinc oxide nano-particles on growth of fodder cowpea and soil microbiological properties. *Range Management and Agroforestry, 38*(2): 208–214.

Summit, W. F. (1996). World Food Summit, 1996. 347–360.

Sun, T., Yan, Y., Zhao, Y., Guo, F., and Jiang, C. (2012). Copper oxide nanoparticles induce autophagic cell death in a549 cells. *PLoS ONE, 7*(8): 1–7.

Thounaojam, T. C., Panda, P., Mazumdar, P., Kumar, D., Sharma, G. D., Sahoo, L., and Panda, S. K. (2012). Excess copper induced oxidative stress and response of antioxidants in rice. *Pl. Physiol. and Biochem.*, *53*: 33–39.

Tiwari, Kumar, P., Kumar, A., and Pratap, V. (2019). Ecotoxicology and Environmental Safety Liquid assisted pulsed laser ablation synthesized copper oxide nanoparticles (CuO-NPs) and their differential impact on rice seedlings. *Ecotoxico. and Env. Safety*, *176*: 321–329.

Vannini, C., Domingo, G., Onelli, E., De Mattia, F., Bruni, I., Marsoni, M., and Bracale, M. (2014). Phytotoxic and genotoxic effects of silver nanoparticles exposure on germinating wheat seedlings. *J. Pl. Physiol.*, *171*(13): 1142–1148.

Yadav, B., Singh, R., and Kumar, A. (2013). Effect of micronutrients and fungicides on spot blotch of wheat. *Vegetos*, *26*(2): 212–219.

Yasur, J., and Rani, P. U. (2013). Environmental effects of nanosilver: Impact on castor seed germination, seedling growth, and plant physiology. *Env. Sci. and Pollut. Res.*, *20*(12): 8636–8648.

Yiyu, Yang, S., Su, X., Wang, Zhao, X., Bi, M., He, Q., and Chen, Y. (2020). Copper oxide nanoparticles inhibited denitrifying enzymes and electron transport system activities to influence soil denitrification and N_2O emission. *Chemosphere*, 245: 125394.

Zhang, H., Wang, R., Chen, Z., Cui, P., Lu, H., Yang, Y., and Zhang, H. (2021). The effect of zinc oxide nanoparticles for enhancing rice (*Oryza sativa* L.) yield and quality. *Agri. (Switzerland)*, *11*(12).

Appendices

Appendix – I

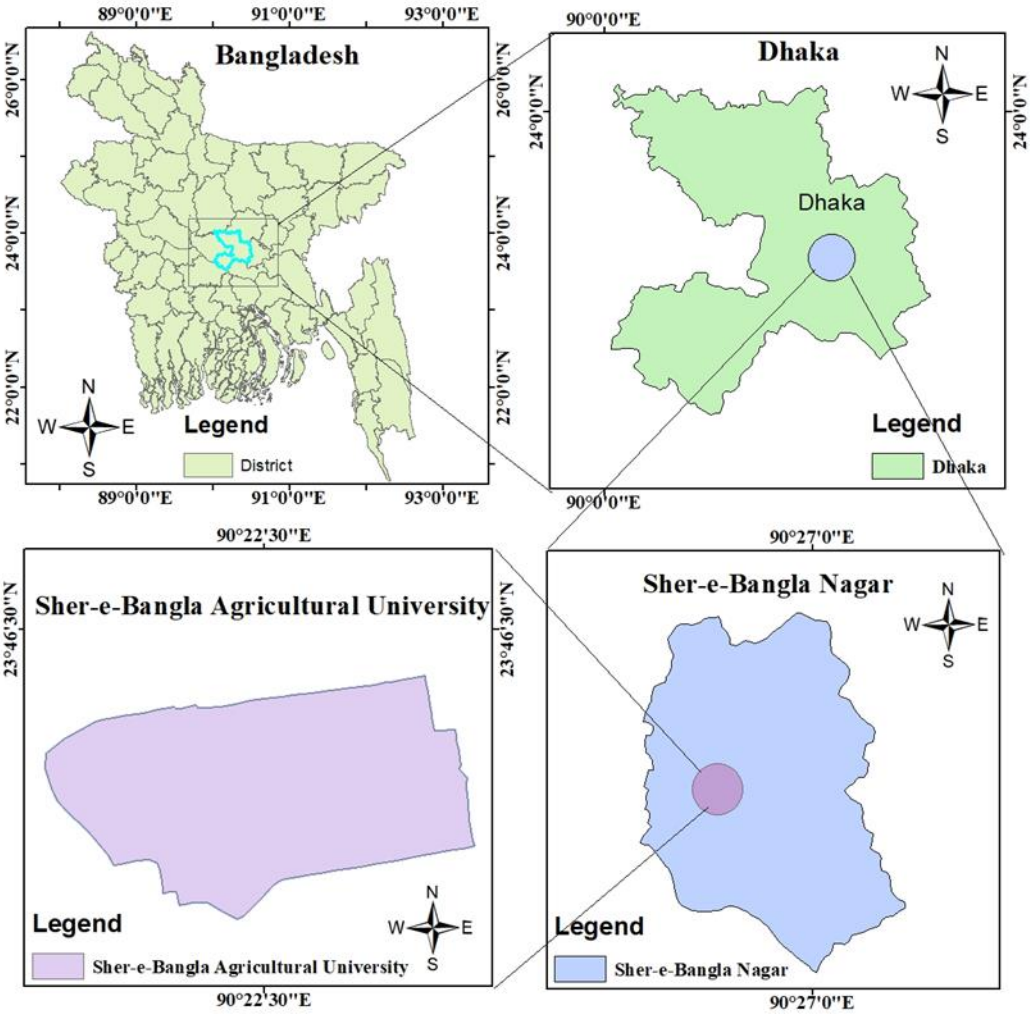

Fig: Location of the experimental site

Appendix – II

Characteristics of experimental soil was analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field –

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairy leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not applicable

Source: SRDI (Soil Resource Development Institute), Farmgate, Dhaka.

B. Physical and chemical properties of the Initial soil –

Characteristics value	Value
Particle size analysis - %Sand %Silt %Clay	 27 43 30
Textural class	Silty-clay
P^H	5.6
Organic Carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (PPM)	20.00
Exchangeable K (me/100g soil)	0.10
Available S (PPM)	45

Source: SRDI (Soil Resource Development Institute), Farmgate, Dhaka

Appendix III

Monthly record of air temperature, rainfall and relative humidity during the period from December, 2019 – June, 2020

Month	RH (%)	Air Temperature (^{0}C)			Rainfall (mm)
		Max	Min	Mean	
December	64.03226	25.04333	15.42581	20.23457	5
January	57.5	27.17419	14.60968	20.891935	21
February	59.94643	28.38214	16.85714	22.61964	1
March	56.03279	31.5129	21.11935	26.316125	30
April	64.96667	33.67667	23.64667	28.66167	128
May	75.54098	34.8871	26.36774	30.62742	300
June	78.76667	33.58	26.58	30.08	271

Source: Bangladesh Meteorological Department (BMD), Agargaon, Dhaka.

Appendix IV

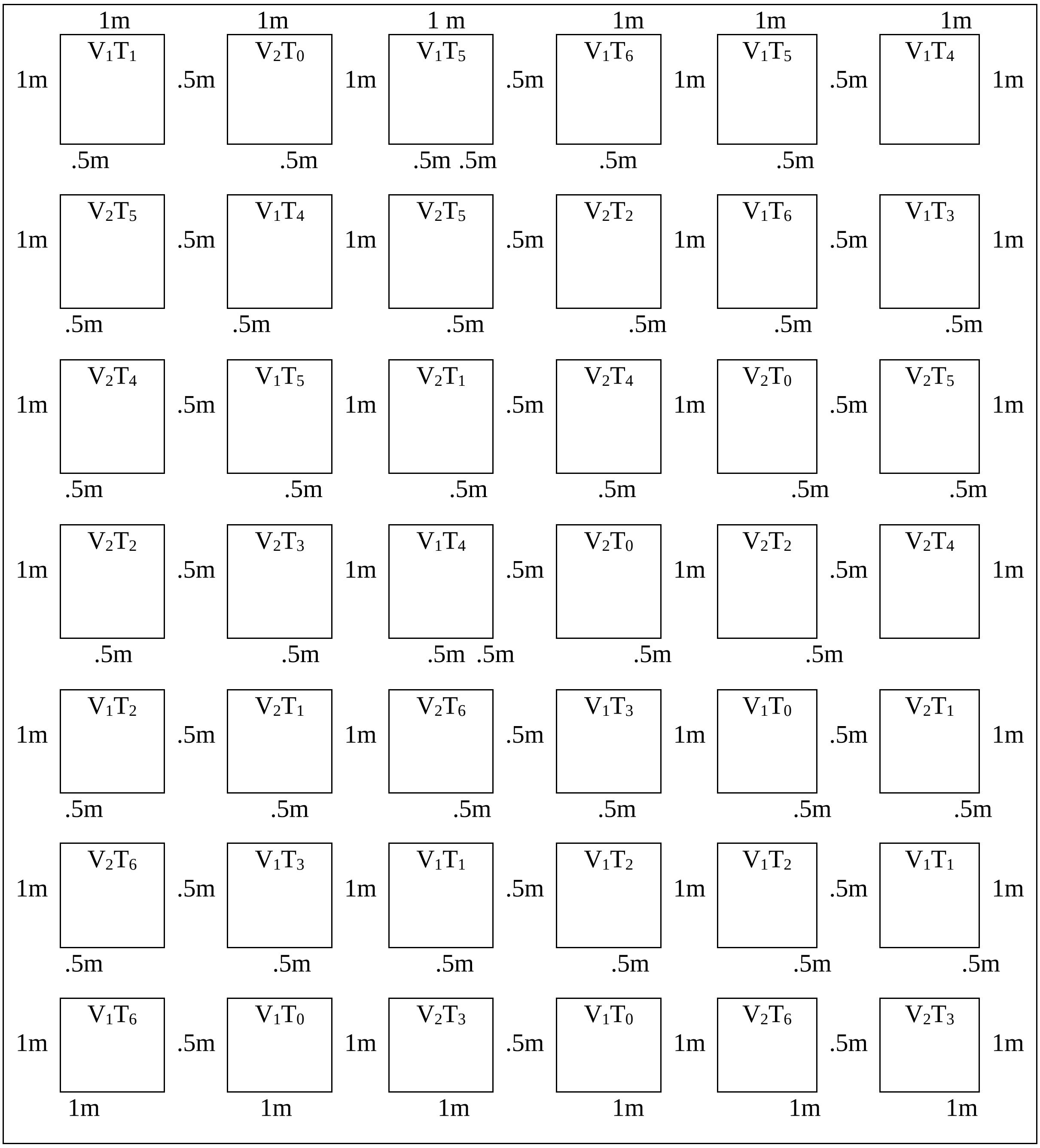

Fig: Layout and Randomization

Appendix V

A. Recommended dose of fertilizer (BRRI dhan28)

Fertilizer Name	Recommend dose/ha	Recommend dose/4m^2
Urea	225 kg	90 g
TSP	50 kg	20 g
MoP	100 kg	40 g
Gypsum	75 kg	30 g
$ZnSO_4$	5 kg	2 g

B. Recommended dose of fertilizer (BRRI dhan63)

Fertilizer Name	Recommend dose/ha	Recommend dose/4m^2
Urea	225 kg	90 g
TSP	75 kg	30 g
MoP	100 kg	40 g
Gypsum	100 kg	40 g
$ZnSO_4$	10 kg	4 g

Appendix VI

Work schedule for experimentation

Serial no.	Work has been done	Time of the work					
		Dec	Jan	Feb	Mar	Apr	May
1	Seed collection, sprouting and sowing						
2	Transplantation of seedlings						
3	Fertilizer application and Top dressing						
4	Gap filling						
5	Weeding						
6	Roughing						
7	Irrigation and Drainage						
8	Pesticide application						
9	1st treatment						
10	2nd treatment						
11	3rd treatment						
12	4th treatment						
13	5th treatment						
14	Harvesting						
15	Data collection						

Appendix VII

Balanced ANOVA for 25 DAT plant height (cm) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	1.84	0.92	
Variety	1	4.17	4.17	4.34^{NS}
Treatment	6	108.44	18.07	18.79 ^{NS}
Combination	6	41.65	6.94	7.22 ^{NS}
Error	26	25.00	0.96	
Total	41	181.12		

Appendix VIII

Balanced ANOVA for 40DAT plant height (cm) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	2.93	1.46	
Variety	1	0.35	0.35	0.42^{NS}
Treatment	6	66.76	11.12	13.16 ^{NS}
Combination	6	42.70	7.11	8.42 ^{NS}
Error	26	21.98	0.84	
Total	41	134.74		

Appendix IX

Balanced ANOVA for 55DAT plant height (cm) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	0.96	0.48	
Variety	1	1.90	1.90	1.51^{NS}
Treatment	6	28.64	4.77	3.78^{NS}
Combination	6	114.05	19.00	15.04 ^{NS}
Error	26	32.85	1.26	
Total	41	178.42		

Appendix X

Balanced ANOVA for 70DAT plant height (cm) at 5% level of significance

SOURCE OF VARIATION	DF	SUM Of SQUARE	MEAN SQUARE	F RATIO
Replication	2	10.54	5.27	
Variety	1	831.70	831.70	165.95*
Treatment	6	89.12	14.85	2.96^{NS}
Combination	6	108.52	18.08	3.61^{NS}
Error	26	130.31	5.01	
Total	41	1170.21		

Appendix XI

Balanced ANOVA for 150DAT (At harvest) data plant height (cm) at 5% level of significance

SOURCE OF VARIATION	DF	SUM Of SQUARE	MEAN SQUARE	F RATIO
Replication	2	4.83	2.42	
Variety	1	821.94	821.94	147.98*
Treatment	6	89.95	14.99	2.70 ^{NS}
Combination	6	106.72	17.78	3.20 ^{NS}
Error	26	144.41	5.55	
Total	41	1167.88		

Appendix XII

Balanced ANOVA for 40 DAT dry matter (g) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	0.10	0.52E-01	
Variety	1	16.49	16.49	65.54*
Treatment	6	107.23	17.87	71.02 ^{NS}
Combination	6	121.66	20.27	80.57 ^{NS}
Error	26	6.54	0.25	
Total	41	252.05		

Appendix XIII

Balanced ANOVA for 55 DAT dry matter (g) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	1.78	0.89	
Variety	1	15.94	15.94	15.96*
Treatment	6	208.62	34.77	34.82 ^{NS}
Combination	6	237.58	39.59	39.68 ^{NS}
Error	26	25.96	0.99	
Total	41	489.89		

Appendix XIV

Balanced ANOVA for 70 DAT dry matter (g) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	2.07	1.03	2.05
Variety	1	18.97	18.97	37.55*
Treatment	6	488.68	81.44	161.19 ^{NS}
Combination	6	143.24	23.87	47.25 ^{NS}
Error	26	13.13	0.50	
Total	41	666.10		

Appendix XV

Balanced ANOVA for 150DAT (At harvest) dry matter (g) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	8.02	4.01	
Variety	1	194.14	194.14	85.75*
Treatment	6	1561.25	260.20	114.93 NS
Combination	6	139.11	23.18	10.24 NS
Error	26	58.86	2.26	
Total	41	1961.40		

Appendix XVI

Balanced ANOVA for 25 DAT total tiller hill^{-1} (number) at 5% level of significance

SOURCE OF VARIATION	DF	SUM Of SQUARE	MEAN SQUARE	F RATIO
Replication	2	2.71	1.35	
Variety	1	0.27E-14	0.27E-14	0.00NS
Treatment	6	4.14	0.69	2.26 NS
Combination	6	2.33	.038	1.27 NS
Error	26	7.95	0.30	
Total	41	17.14		

Appendix XVII

Balanced ANOVA for 40 DAT total tiller hill^{-1} (number) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	2.33	1.16	
Variety	1	1.52	1.52	1.34^{NS}
Treatment	6	25.28	4.21	3.69 ^{NS}
Combination	6	22.80	3.80	3.33 ^{NS}
Error	26	29.66	1.14	
Total	41	81.61		

Appendix XVIII

Balanced ANOVA for 55 DAT total tiller hill^{-1} (number) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUAR E	F RATIO
Replication	2	3.61	1.80	
Variety	1	0.85	0.85	1.09^{NS}
Treatment	6	19.90	3.31	4.23 ^{NS}
Combination	6	13.14	2.19	2.79 ^{NS}
Error	26	20.38	0.78	
Total	41	57.90		

Appendix XIX

Balanced ANOVA for 70 DAT total tiller hill^{-1} (number) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	10.33	5.16	
Variety	1	2.38	2.38	2.54^{NS}
Treatment	6	14.57	2.42	2.59 ^{NS}
Combination	6	6.28	1.04	1.12 ^{NS}
Error	26	24.33	0.93	
Total	41	57.90		

Appendix XX

Balanced ANOVA for 150DAT (At harvest) data total tiller hill^{-1} (number) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	10.33	5.16	
Variety	1	2.38	2.38	2.54^{NS}
Treatment	6	14.57	2.42	2.59 ^{NS}
Combination	6	6.28	1.04	1.12 ^{NS}
Error	26	24.33	0.93	
Total	41	57.90		

Appendix XXI

Balanced ANOVA for percent of effective tiller hill^{-1} at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	43.34	21.66	
Variety	1	70.93	70.92	1.57 ^{NS}
Treatment	6	947.33	157.87	3.50^{NS}
Combination	6	950.28	158.37	3.51 ^{NS}
Error	26	1172.38	45.09	1.00
Total	41	3184.14		

Appendix XXII

Balanced ANOVA for percent of non-effective tiller hill^{-1} at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	16.67	21.66	
Variety	1	29.58	70.92	1.57^{NS}
Treatment	6	1095.49	157.87	3.50^{NS}
Combination	6	989.58	158.37	3.51^{NS}
Error	26	1134.75	45.01	
Total	41	3266.07		

Appendix XXIII

Balanced ANOVA for filled grain panicle^{-1} (number) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	12.19	6.09	
Variety	1	5.35	5.35	0.85^{NS}
Treatment	6	417.61	69.60	11.00 ^{NS}
Combination	6	84.47	14.07	2.23 ^{NS}
Error	26	164.47	6.32	
Total	41	684.11		

Appendix XXIV

Balanced ANOVA for unfilled grain panicle^{-1} (number) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	0.04	0.02	
Variety	1	4.66	4.66	5.21*
Treatment	6	130.23	21.70	24.24 ^{NS}
Combination	6	19.66	3.27	3.66 ^{NS}
Error	26	23.28	0.89	
Total	41	177.90		

Appendix XXV

Balanced ANOVA for 1000-seed weight (g) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	0.01	0.005	
Variety	1	10.31	10.31	918.42*
Treatment	6	0.01	0.001	0.15^{NS}
Combination	6	0.0008	0.0001	0.01^{NS}
Error	26	0.29	0.01	
Total	41	10.62		

Appendix XXVI

Balanced ANOVA for grain yield (t ha^{-1}) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	0.006	0.003	
Variety	1	13.98	13.98	10625.27*
Treatment	6	1.52	0.25	193.26^{NS}
Combination	6	0.40	0.06	51.39^{NS}
Error	26	0.03	0.00	
Total	41	15.96		

Appendix XXVII

Balanced ANOVA for straw yield (t ha^{-1}) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	0.20	0.10	
Variety	1	11.26	11.26	190.47*
Treatment	6	2.39	0.39	6.75 ^{NS}
Combination	6	1.66	0.27	4.70 ^{NS}
Error	26	1.53	0.05	
Total	41	17.06		

Appendix XXVIII

Balanced ANOVA for biological yield (t ha^{-1}) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	0.26	0.13	
Variety	1	50.35	50.35	797.84*
Treatment	6	7.41	1.23	19.59 ^{NS}
Combination	6	2.98	0.49	7.88 ^{NS}
Error	26	1.64	0.06	
Total	41	62.66		

Appendix XXIX

Balanced ANOVA for harvest index (%) at 5% level of significance

SOURCE OF VARIATION	DF	SUM OF SQUARE	MEAN SQUARE	F RATIO
Replication	2	3.61	1.80	
Variety	1	0.53	0.53	0.39*
Treatment	6	13.27	2.21	1.58 ^{NS}
Combination	6	31.90	5.31	3.80 ^{NS}
Error	26	36.37	1.39	
Total	41	85.70		

Appendix XXX

Some photos during experimentation

Figure: Seed bed

Figure: Layout preparation

Figure: Collection of seedlings

Figure: Transplanting of seedlings

Figure: Plot tagging

Figure: Plant before first treatment

Figure: Plant selection for data collection

Figure: Application of first treatment

Figure: Plant height data collection

Figure: Tiller number data collection

Figure: Plant collection for dry matter calculation

Figure: Uprooting plant for dry matter calculation

Figure: Application of third treatment

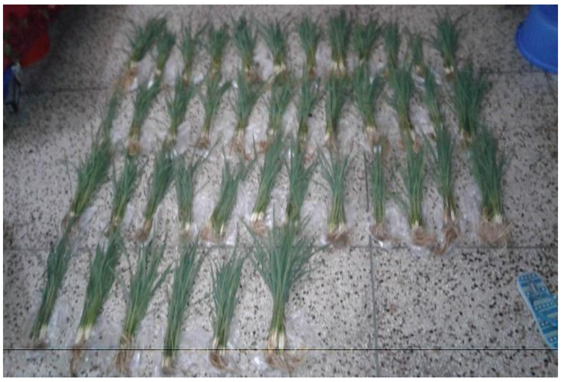

Figure: Air drying for collecting dry matter weight

Figure: Flowering plant