IMPROVEMENT OF BORO SEEDLING STRENGTH AND YIELD THROUGH SEED PRIMING AND SEEDBED SOIL AMENDMENT

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JUNE, 2022

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A Thesis
Submitted to the Department of Soil Science,
Sher-e-Bangla Agricultural University, Dhaka-1207
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (M.S.)
IN
SOIL SCIENCE

SEMESTER: JANUARY- JUNE, 2022

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CERTIFICATE

This is to certify that thesis entitled, **“Improvement of Boro Seedling Strength and Yield through Seed Priming and Seedbed Soil Amendment”** submitted to the Department of Soil science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirement for the degree of **Master of science (M.S.) in Soil Science,** embodies the result of a piece of bona-fide research work carried out by **Md. Abdullah Al Mamun, registration no: 20-11111** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2022

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Dedication

To my beloved parents & respected teachers. Thanks for your endless affection, supports and sacrifices.

ACKNOWLEDGEMENT

All praises to the Almighty Allah, the great, the gracious, merciful and supreme ruler of the universe who enables me to complete this present piece of work for the degree of Master of Science (M.S.) in the Department of Soil Science.

The author would like to express his deepest sense of gratitude, respect to her research supervisor, ***Prof. Dr. Mohammad Issak,*** *Department of Soil Science, Sher- e-Bangla Agricultural University, for her kind and scholastic guidance, untiring effort, valuable suggestions, inspiration, extending generous help and encouragement during the research work and guidance in preparation of manuscript of the thesis.*

The author sincerely expresses his deepest respect and boundless gratitude to his co-supervisor ***Dr. Amena Sultana****, Senior Scientific Officer, Bangladesh Rice Research Institute for his helpful suggestion and valuable advice during the preparation of this manuscript.*

It is highly appreciating words for ***Prof. Dr. Mohammad Saiful Islam Bhuiyan,*** *Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University, for the facilities provided, in carrying out this work. The author also acknowledges with deep regards the help and cooperation received from his respected teachers and stuff of the Department of Soil Science, Sher-e-Bangla Agricultural University while carrying out this work.*

The author feels proud to express his sincere appreciation and gratitude to Ministry of Science and Technology, The People's Republic of Bangladesh for awarding me National Science and Technology (NST) fellowship.

At last but not the least, the author feels indebtedness to his beloved parents and brother whose sacrifice, inspiration, encouragement and continuous blessing paved the way to his higher education and reach at this stage. May Allah bless us all.

Dated: June, 2022

Place: Dhaka, Bangladesh

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IMPROVEMENT OF BORO SEEDLING STRENGTH AND YIELD THROUGH SEED PRIMING AND SEEDBED SOIL AMENDMENT

ABSTRACT

A pot experiment was conducted under the net house of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, during December 2020 to May 2021, to study on yield performance of a rice variety (BRRI dhan84) as influenced by the effects of seed priming with salicylic acid (SA) and using organic material (Shrimp Shell Powder, SSPd) in the seedbed. Fourteen (14inches) size plastic pots were used in the experiment having height (10.5inches) and diameter (9.5inches). The pots were filled with 10 kg SAU field moist soils having the texture silty clay loam soil. The experiment was laid out in a Completely Randomized Design (CRD) having six treatments (T_1= 0 µM Salicylic Acid + 0% Shrimp Shell Powder, T_2 = 0 µM Salicylic Acid + 0.25% Shrimp Shell Powder, T_3 = 0 µM Salicylic Acid + 0.5% Shrimp Shell Powder, T_4 = 50 µM Salicylic Acid + 0% Shrimp Shell Powder, T_5 = 50 µM Salicylic Acid + 0.25 % Shrimp Shell Powder, T_6 = 50 µM Salicylic Acid + 0.5% Shrimp Shell Powder) with twenty four (24) replications. A significant variation was observed in the germination (%), seedlings height, biomass production, seedling strength and chemical properties of the seedbed soils due to the seed priming with SA and application of Shrimp Shell Powder in the seedbed. The maximum germination (79%), seedlings height (24.65cm), seedling fresh weight (593.29mg), seedling oven dry weight (396.14mg), seedling strength (18.08mg cm^{-1}), grain yield sundry weight (66.35g pot^{-1}), grain yield oven dry weight (58.17g pot^{-1}) and straw yield (70.25g pot^{-1}) were observed in the treatment T_6. Otherwise, the minimum germination (61%), seedlings height (19.52cm), seedling fresh weight (239.67mg), seedling oven dry weight (144.84mg), seedling strength (7.42mg cm^{-1}), grain yield sundry weight (49.59g pot^{-1}), grain yield oven dry weight (43.61 g pot^{-1}) and straw weight (51.12g pot^{-1}) were recorded in the treatment T_1 (control). Whereas, the maximum level of OC (0.78%), OM (1.34%), pH (6.4), available Phosphorus (39.34 ppm) and available Sulphur (30.36ppm) were recorded in the treatment T_6. Otherwise, the minimum level of OC (0.64%), OM (1.1%), pH (6.3), available Phosphorus (17.69ppm) and available Sulphur (17.22ppm) were recorded in the treatment T_1 (control). Shrimp Shell Powder increased the level of organic matter in a dose dependent manner. Quality of the rice seedlings were improved due to the application of the organic matter in a dose dependent manner and the treatment T_6 (50µM Salicylic Acid + 0.5 % Shrimp Shell Powder) was the more effective than other treatments. Most of the morphological, yield attributes and grain yield were increased with increasing the dose of Shrimp Shell Powder. Maximum grain yield was observed in T_6 treatment followed by T_5,T_4,T_3, T_2 and T_1 (control). So overall result indicated that application of shrimp shell powder in soil has significant impact on growth and yield of BRRI dhan84 and some on chemical properties of soil.

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ABBREVIATIONS

Abbreviations	Full form	Abbreviations	Full form
Agric.	Agriculture	L	Liter
AEZ	Agro-Ecological Zone	mL	Milliliter
et al.	And others	Meqs	Milliequivalents
App.	Applied	µM	Micro mole
SA	Salicylic Acid	Mg	Milligram(s)
ha^{-1}	Per hectare	Mm	Millimeter
Res.	Research and Resource	MSL	Mean sea level
Biol.	Biology	MT	Metricton
Biotechnol.	Biotechnology	N	North
Bot.	Botany	Nutr.	Nutrition
Cm	Centimeter	Regul.	Regulation
Cv.	Cultivar	DAS	Days after sowing
°C	Degree Celsius	Rev.	Review
Dept.	Department	Sci.	Science
Dev.	Development	Soc.	Society
DF	Dry Flowables	Wt.	Weight
CRM	Chitosan raw materials	MoP	Muriate of Potash
Eds.	Editors	Technol.	Technology
EC	Emulsifiable concentrate	Trop.	Tropical
Entomol.	Entomology	Thai.	Thailand
Environ.	Environments	U.K.	United Kingdom
Frw.	Fresh weight	Odwt.	Oven dry weight
TSP	Triple super phosphate	Univ.	University
G	Gram	Min	Minimum
Hort.	Horticulture	WP	Wet table powder
Intl.	International	Sl.	Serial
J.	Journal	%	Percentage
Kg	Kilogram	No.	Number
LSD	Least Significant Difference	USA	United States of America
FAO	Food and Agriculture Organization		
SSPD	Shrimp Shell Powder		
SPAD	Soil plant analysis development		
SRDI	Soil Resource Development Institute		
AJBGE	Asian Journal of Biotechnology and Genetic Engineering		
BARI	Bangladesh Agricultural Research Institute		
BBS	Bangladesh Bureau of Statistics		
SAU	Sher-e-Bangla Agricultural University		

CHAPTER 1

Introduction

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop and a primary food source for more than one-third of world's population (Sarkar *et al.,* 2017). Worldwide, rice provides 27% of dietary energy supply and 20% dietary protein (Kueneman, 2006). It constitutes 95% of the cereal consumed and supplies more than 80% of the calories and about 50% of the protein in the diet of the general people of Bangladesh (Yusuf *et al*, 1997). World's rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth (Maclean *et al.,* 2002), and therefore, meeting this ever increasing rice demand in a sustainable way with shrinking natural resources is a great challenge. In Bangladesh, majority of food grains comes from rice. Rice has tremendous influence on agrarian economy of the country. Annual production of rice in Bangladesh is about 36.28 million tons from 11.52 million ha of land (BBS, 2018). According to the USDA report in 2021 rice production for the 2020-21 marketing year is expected to rise to 36.3 million tons in Bangladesh as further cultivation of hybrid and high yield variety plantings increase. The country is expected to import 200,000 tons of rice in the 2020-21 marketing year to ease food security tensions brought on by the COVID-19 pandemic (USDA, 2021).

There are three distinct growing seasons of rice in Bangladesh, according to changes in seasonal conditions such as *Aus, Aman and Boro.* More than half of the total production (55.50 %) is obtained in *Boro* season occurring in December–May, second largest production in *Aman* season (37.90 %) occurring in July-November and little contribution from *Aus* season (6.60 %) occurring in April-June (APCAS, 2018). Among three growing seasons *(Aus, Aman and Boro), Boro* rice is the most important rice crops for Bangladesh with respect to its high yield and contribution to rice production. *Boro* cultivation area has declined to 4.75 million hectares in 2020, which was 4.9 million hectares in 2019. The country produced an all-time-high 20.03 million tons of *Boro* rice in 2019. The government expects to achieve 20.04 million tons of *Boro* production target, although acreage of this major crop fell to a three-year low in 2010 which was due to reason that many farmers, upset with low paddy and rice prices, switched to other crops like corn, vegetables and tobacco etc. (Express, 2021).

Recently, food security especially attaining self-sufficiency in rice production is a burning issue in Bangladesh. The average yield of rice is almost less than 50% of the world average rice grain yield. The national mean yield ($2.60 \mathrm{t\,ha^{-1}}$) of rice in Bangladesh is lower than the potential national yield ($5.40 \mathrm{t\,ha^{-1}}$) and world average yield ($3.70 \mathrm{t\,ha^{-1}}$) (Pingali *et al.,* 1997). The lower yield of transplanted *Boro* rice has been attributed to several reasons. In such condition, increasing rice production can play a vital role. Therefore, attempts must be made to increase the yield per unit area by adopting modern rice cultivars, nutrient management practices and applying improved technology such age of seedling etc.

Chitosan raw material is a natural polymer and one of the chitin derivatives when the degree of deacetylation of chitin reaches about 50% (Rinaudo, 2006). Chitosan raw material is obtained after deacetylation of chitin in which its chemical structure composed of a linear polymer consisting of two subunits, D-glucosamine and N-Acetyl-D-glucosamine linked together by glycosidic bond (Hidangmayum *et al*., 2019). Otherwise, Shrimp shell powder is prepared from the Crustecean by-products through the deacetylation process. Whereas, modified Shrimp shell powder is prepared from the sea shell by-products through sun drying, oven drying, milling, sieving and finally used the powder as the acetylated form having less than two millimeter in size and use the material directly in the main field. The functional properties of Shrimp shell powder such as solubility, biodegradability, and diverse bioactive attributes are related to molecular weight and the degree of deacetylation (Rajoka *et al*., 2019*).* Many studies have differently determined classes of organic matter based on its molecular weight; however, the specific categories are still unclear. Commercially, Shrimp shell powder is classified into three main different classes: low (50-190 kDa), medium (190-310 kDa), and high (310-375 kDa) molecular weight (MW) (Prashanth and Tharanathan, 2007*).*The cationic nature of organic matter is somewhat unique because most of the polysaccharides are usually either neutral or negatively charged in an acidic condition. The unique property allows it to generate electrostatic complexes with other negatively charged synthetic or natural polymers (Rinaudo, 2006). Shrimp shell powder has been, therefore, investigated and developed as a plant bio-stimulant (Katiyar *et al*., 2015; Hidangmayum *et al*., 2019). In plants, Shrimp shell powder elicits numerous defense responses related to biotic and abiotic stresses. It has been utilized effectively in many plantrelated applications to increase plant productivity as well as protect plants against the attack of pathogens (Malerba and Cerana, 2018). Previous studies revealed that organic matter has a potential to enhance plant growth as well as increase yield in many crops including apple, wheat, maize and rice (Yang *et al*., 2009; Lizárraga-Paulín *et al*., 2011; Zeng and Luo, 2012; Seang-Ngam *et al*., 2014). In agriculture, Organic matter is used primarily as a natural seed treatment and plant growth enhancer and as an ecologically friendly bio-pesticide substance that boosts the innate ability of plants to defend themselves against fungal infections and increasing grain yield (Linden *et al*., 2000). Grain formation is the result of interaction of genetic, environmental and cultural management practices (Dhillon *et al*., 2018). Among the cultural factor, the seedling age at the time of transplanting is the most important factor deciding uniform stand, growth and yield of rice (Faghani *et al*., 2011). When seedlings stay for an extended period of time in the beds of nursery, primary tiller buds on the lower nodes of main culm become degenerated leading to reduced tillering potential (Mobasser *et al*., 2007). It is reported that tillering potential in rice plant mainly depends on the age of seedling at transplanting (Ali *et al*., 2013 and Pasuquin *et al*., 2008). Transplanting older nursery seedlings besides reducing tiller production also results in early panicle initiation, uneven flowering, shortening vegetative phase and thereby reducing number of grains per panicle ((Jia *et al*., 2014). Pre-anthesis dry matter accumulation determines the sink capacity and final grain yield. Katsura *et al.* (2007) reported that lesser supply of photosynthetic assimilates from source to sink in the older seedlings due to reduced sink capacity. Seedling age at staggered transplanting is an important factor due to its tremendous influence on plant height, tiller production, panicle length, grains panicle^{-1} and other yield contributing characters (Islam and Ahmed, 1981).The crop is suffering from different fungal, bacterial, viral and mycoplasmal diseases. However, in order to defend themselves against these attacks, plants have evolved various constitutive and inducible mechanisms, one such mechanism being the accumulation of large quantities of salicylic acid. Salicylic acid can induce tolerance against high and low temperatures, drought, salinity, ultraviolet light, heavy metal toxicity, diseases and pathogens (Raskin, 1992; Yalpani *et al.,* 1994; Dat *et al*., 1998; Metwally *et al.,* 2003; Sakhabutdinova *et al.,* 2003; Hayat & Ahmad, 2007; Horváth *et al.,* 2007, Farooq *et al.,* 2008b; Hussain *et al.,* 2008, Wang *et al.,* 2009, Thanh *et al.,* 2017). It plays an important role in flowering induction, plant growth and development, synthesis of ethylene, opening and closure of stomata and respiration of plants (Raskin, 1992). Salicylic acid helps stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan *et al.* 2010). Foliar application of salicylic acid increased net photosynthetic rate and proline content in salt stressed plants and may have contributed to the enhanced growth parameters (Khoshbakht and Asgharei, 2015). It increased photosynthetic rates and water use efficiency, decreased stomatal conductance and transpiration rate (Khan *et al*., 2010). It can affect seed germination, cell growth, stomatal opening, expretion of genes associated with senescence and fruit production (Klessing *et al.*, 2009). Plants treated with SA showed increased vigor of early seedling growth (Farooq *et al*., 2008b; Kawano *et al.,* 2013). SA protects plant growth and induces antioxidant defense system under salt stress (Nazar *et al.,* 2011). SA increased photosynthesis, growth and stomatal regulation under abiotic stress conditions. (Khan *et al.,* 2003; Arfan *et al.,* 2007; Issak *et al.,* 2013). Salicylic acid induced stress tolerance and protection against oxidative damage due to various stresses. (Larkindale & Knight, 2002). It is a growth regulator with phenolic nature (Sakhabutdinova *et al*.,2003). Plants pre-treated with Salicylic acid (Larkindale & Knight, 2002) showed induced stress tolerance and protection against oxidative damage due to various stresses. Despite the importance of these chemicals in stress tolerance, little is known about their effects on rice morphology, phenology and physiology.

By considering the above fact, the proposed research work was undertaken to achieve the following objectives:

(i) To examine effects of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the improvement of seedling characters

(ii) To evaluate yield performance of the treated seedlings.

CHAPTER 2

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to impact of late planting with organic material (Shrimp Shell Powder) treated seedlings on yield performance of BRRI dhan84 to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of shrimp shell powder application on seedling characteristics

2.1.1 Seedling fresh weight

Ahmed *et al*. (2020) reported that seedling fresh weight was increased with the application of organic materials in the seedbed. Issak and Sultana (2020) carried out an experiment to observed the role of organic material on the production of quality rice seedlings of BRRI dhan29 was in the field of Sher-e-Bangla Agricultural University, Dhaka and found that the maximum fresh weight (29.14 g) production of 100 seedlings was found in the treatment T_4 having 400g shrimp shell powder m^{-2} and the lowest fresh weight production (12.6g) was found in the treatment T_6 (control) which was significantly different from all other treatments. These results indicate that fresh weight productions of BRRI dhan29 rice seedlings were influenced by the organic material treatments and this might be due its supplementation of plant nutrients and growth regulators. Ouyang and Langlai (2003) reported that seeds of non-heading Chinese cabbage dressed with organic material at the rate ($0.4-0.6$mg g^{-1}) seed and leaf spraying with (20-40μg ml^{-1}) increased fresh weight.

2.1.2 Seedling oven dry weight

Ahmed *et al*. (2020) reported that seedling oven dry weight was increased with the application of organic material (Shrimp Shell Powder) in the seedbed. Issak and Sultana (2017) reported that oven dry weight productions of BRRI dhan29 rice seedlings were influenced by the organic material applications and this might be due its nutritional support to the seedlings, improvement of growth promoting hormonal activity and could improve the biological as well as physio-chemical properties of the seedbed soils. Boonlertnirun *et al.* (2008) conducted an experiment to investigate the effect of organic material application in rice production and found that application of organic material stimulates the seedling dry matter weight significantly. Martinez *et al.* (2007) carried out an experiment to study the Influence of seed treatment with shrimp shell powder on tomato (*Lycopersicum esculentum* L.) plant growth and reported that in general, the best response was obtained when seeds were treated with 1 mgl^{-1} organic matter during four hours, as this concentration stimulated significantly plant dry weight, although the other indicators were not modified.

2.1.3 Seedling height

Ahmed *et al*. (2020) reported that seedling height was increased with the application of organic material (Shrimp Shell Powder) in the seedbed. Issak and Sultana (2020) carried out an experiment to observed the role of organic material on the production of quality rice seedlings of BRRI dhan29 and found that Boro rice seedlings production were improved by using the organic material in the seedbed. Ziani *et al.* (2010) reported that seeds treated with organic material resulted in a better growth of the seedlings (e.g. longer and better developed radical and greener hypocotyls) and lower chance of being infected by fungi in comparison with the untreated seeds. The observed growth improvement by organic material could be also related to the incorporation of nutrients (nitrogen) from shrimp shell powder. Boonlertnirun *et al.* (2008) conducted an experiment to investigate the effect of organic material application in rice production and reported that, organic material is an actual biopolymer which stimulates growth and increases yield of plants as well as induces the immune system of plants. Ouyang and Langlai (2003) who studied the Chinese cabbage (*Brassica campestris*) cv. Dwarf hybrid No-1, found that seed dressing with 0.4-0.6 mg g^{-1} seed and leaf spraying 20-40μg ml^{-1} increased plant height and leaf area of Chinese cabbage. Khan *et al.* (2002) reported that foliar application of oligomeric organic matter did not affect plant height of soybean. Tsugita *et al.* (1993) carried out a study on Chitin oligosaccharides elicit lignification in wounded Rice leaves and found that organic material promotes shoot and root growth. Bolto *et al.* (2004) carried out and experiment on Ion exchange for the removal of natural organic matter and found that organic material can increase the microbial population and transforms organic nutrient into inorganic nutrient which is easily absorbed by the plant roots. Arif *et al*. (2015) revealed that application of modified organic material increased tomato seedling height, fresh and dry weight of the seedlings, seedbed soil pH, seedbed organic carbon (%) & organic matter (%), number of flowers/plant, fruits/plant, fruit size and fruit yield over control. Sultana (2007) applied Miyobi on rice and reported that plant height increased in Miyobi applied plant than control. Kobayashi *et al.* (1989); conducted different experiment which revealed that the increasing of plant height obtain through the application of organic material along with N, P, K and S was also reported by many other scientists.

2.1.4 Seedling strength

Ahmed *et al*. (2020) reported that seedling strength was increased with the application of shrimp shell powder in the seedbed. Issak and Sultana (2017) carried out an experiment to observed the role of organic material (Shrimp Shell Powder) on the production of quality rice seedlings of BRRI dhan29 and reported that application of different level of organic material influenced the seedling strength of rice plant and maximum seedling strength (5.79 mg cm^{-1}) was obtained in the T_5 treatment having shrimp shell powder @ 500 gm^{-2} whereas the minimum seedling strength (10.80mg cm^{-1}) was obtained in the T_6 treatment (control). Boonlertnirun *et al.* (2008) found that application of organic material stimulates the seedling strength significantly.

2.1.5 Tillers hill^{-1}

Ahmed *et al.* (2013) carried out an experiment at the field laboratory, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during the period from November 2011 to April 2012 to investigate the effect of organic material on growth, yield contributing characters and yield of BRRI dhan29 and reported that The foliar application of organic material had significant effect on the production of tillers hill^{-1} in rice. The result revealed that organic material treated plants produced the higher number of tillers compare to control. The maximum number of tillers hill^{-1} (9.33, 13.67 and 16.67) was observed in 50 mgL^{-1} followed by 75 mgL^{-1} Organic material (8.33, 12.33 and 15.33) at 30, 60 and 90 DAT, respectively. In contrast, the minimum number of tillers hill^{-1} (7.33, 10.33 and 13.33, respectively) was found in control. Krishna *et al.* (2009) conducted an experiment in Karnataka and revealed that the 12 days old seedling produced more number of tillers hill^{-1} at harvest. The 8 days old seedling flowered and matured about four to five days early compared to 5 days old seedlings. The treatment combination of 12 days old seedling with wider spacing recorded maximum seed yield per hectare. Significantly higher seed yield (3.27 tha^{-1}) and less spikelet sterility (16.72 per cent) recorded by 12 days old seedlings. Sridevi and Chellamuthu (2007) observed that the combination of single and young seedling hill^{-1} with square planting and cone-weeding gave highest tiller m^{-2} and grain yield than the normal seedling or multiple seedling with rectangular planting and hand weeding. Uphoff (2002) also stated that transplanting of very young seedlings usually 8-10 days old and not more than 15 days will have better tillering and rooting and it was reduced if transplanting was done after the 4th phyllochron usually about 15 days after emergence.

2.1.6 Effective tiller hill^{-1}

Ahmed *et al*. (2020) conducted a field experiment at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, to examine effect of organic material (Shrimp Shell Powder) on yield maximization of BRRI dhan49. The experiment was laid out in a Randomized Complete Block Design (RCBD) having four treatments with five replications. The organic materials (Shrimp Shell Powder) were applied in different doses and methods (Seedbed and main field applied methods). The treatment combinations were as follows: T_1: Seedbed applied @ 0 gm^{-2} + Main field applied @ 0 t ha^{-1} (Control); T_2: Seedbed applied @ 0 gm^{-2}+ Main field applied @ 0.5 t ha^{-1}; T_3: Seedbed applied @ 250 gm^{-2}+ Main field applied @ 0 t ha^{-1}; T_4: Seedbed applied @ 250 gm^{-2} + Main field applied @ 0.5 t ha^{-1}. Experiment result revealed that, different level of organic material significantly effects on effect tillers hill^{-1}and the highest number of effective tillers hill^{-1}(14) was obtained in the T_3 whereas the lowest number of effective tillers hill^{-1}(11.67) was obtained in the T_1 control treatment. It was observed that the organic materials application in soil the increases the effective tillers hill^{-1}. Boonlertnirun *et al.* (2012) showed that application methods of organic materials significantly affected tiller number per plant. Sultana *et al.*(2020) conducted a field experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from July 2016 to December 2016 to find out the effect of seedlings age and different nitrogen (N) levels on the yield performance of transplant Aman rice (cv. Binadhan-15). The experiment comprised four ages of seedlings viz., 15, 20, 25, 30 days old and four levels of nitrogen viz., 0, 55, 75 and 95 kg N ha^{-1}following randomized complete block design (RCBD) with three replications. The effect of age of seedling, nitrogen levels and their interactions were significant on growth, yield and yield contributing characters of transplant Amanrice. By using optimum seedling age at 15 DAT recorded the highest number of effective tillers $plant^{-1}$ (8.29) at harvest respectively. Ali *et al.* (2013) reported more effective tillers $hill^{-1}$. (24.9) when seedlings of 15 days' age were transplanted while 30 days old seedlings gave minimum number of effective tillers (15.6). Kavitha and Ganesh raja (2012) reported from Madurai that 14 days old seedling recorded significantly higher number of productive tillers (m^{-2}) over 18 and 22 days old seedlings under SRI. Faghani*et al.* (2011) found the significant effect of seedlings age on tillering pattern, and concluded that the maximum tillers $hill^{-1}$. (16.3) were recorded by transplanting 25 days old seedlings while 35 days' seedlings gave minimum tillers $hill^{-1}$. (15.3). Oteng and Anna (2003) from Ghana (South Africa) observed that 10-15 day sold seedlings produced more number of effective tillers than those of 15-20 days and 20-25 days old seedlings under SRI practices.

2.2 Grain Yield

Behboudi *et al.* (2018) reported that organic materials (Shrimp Shell Powder) uses significantly improved the number of grain per spike and grain yield as compared to that in control. Ahmed *et al.* (2013) carried out a study to investigate the effect of organic materials on growth and yield of rice cv. BRRI dhan29 observed significant effect of organic materials on grain yield of rice. The result revealed that 50 mgL^{-1} of organic materials treated plants produced the highest grain yield (7.05tha^{-1}) followed by 75 mgL^{-1} (6.77t ha^{-1}) and 100 mgL^{-1} (6.14 t ha^{-1}) of organic materials where 75 and 100 mg L^{-1}organic materials were statistically same. On the other hand, the lowest grain yield (5.83 tha^{-1}) was observed at control treatment. Nguyen and Tran (2013) carried out an experiment to know the effect of application of organic materials solutions for rice production in Vietnam and reported that, the organic materials produced from shrimp shells using dilute acetic acid proved effective in controlling plants infection by microbial agents leading to higher yields. The field the study showed that the yields of rice significantly increased (~31%) after applying organic materials solution. In general, applying organic materials increased rice production and reduced cost of production significantly. Abdel-Mawgoud *et al.* (2010) reported that application of organic material at 2 mgL^{-1} improved yield components (number and weight) of strawberry organic materials application had a tendency to increase grain yield of rice plants over than unapplied seed. Boonlertnirun *et al.* 2006 reported that rice yield cultivar Suphan Buri was significantly increased over the control (no organic materials) after application of polymeric organic materials at the concentration of 20 ppm. Krivtsov *et al.* (1996) which revealed that wheat plants treated with polymeric or oligomeric chitosan increased spike weight and grain yield.

2.3 Straw Yield

Sultana *et al.* (2015) conducted a field experiment to investigate the impact of foliar application of oligo organic materials improves morphological character and yield in rice. The experiment was done with randomized complete block with four replications. BINA Dhan-14 seeds were soaked with 100 ppm o-chitosan for 24 hours whereas the control seeds were soaked in distilled water. Four different concentrations were used in this experiment that is 0, 40, 80 and 100 ppm oligomeric organic materials and four times foliar spray after germination (on day 3, 17, 55 and 70 at field stages) were carried out. In the control treatment only water was sprayed. Experiment result revealed that straw yield shows significant differences between control plants and foliar sprayed organic materials plants and highest straw yield (4.38 tha^{-1}) was recorded under 100 ppm oligomeric organic materials and lowest straw yield (3.24 tha^{-1}) was observed under 0 ppm oligomeric organic materials. Kananont *et al.* (2015) carried out an experiment to improving the rice performance by fermented chitin West with Fermented chitin waste (FCW). The experiment consisted with three levels of FCW (Fermented chitin waste) @ (0.25%, 0.50% and 1.0% (w/w)) along with CF = soil supplemented with chemical fertilizer and CMF = soil supplemented with chicken manure fertilizer. The experiment result results revealed that FCW @ 1% the straw yield differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment. Panigrahi *et al*. (2014) conducted a field experiment during the kharif season of 2007 and 2008 at OUAT, Bhubaneswar on basmati rice varieties under system ofrice intensification (SRI) that observed growth, yield and economics of basmati rice did not vary much between the crops planted with 10 and 15-day old seedlings. Bagheri *et al.* (2011) noticed that the highest (635.8 g m^{-2}) straw yield was obtained from 20 days old seedlings over 30 and 40 days. Rajesh and Thanunathan (2003) reported that the seedling age had significant difference on straw yield. Planting of 40 day old seedlings found to be optimum to get significantly higher (5.63 tha^{-1}) straw yield compared to 30 (5.09 tha^{-1}) and 50 (4.76 tha^{-1}) days old seedlings. Sharma and Ghosh (1998) stated that younger seedlings produced significantly higher straw (7.53 tha^{-1}) yields as compared to older seedlings from their studies on hybrids rice.

2.4 Biological yield

Ahmed (2015) carried out an experiment to know the Performance of BRRI dhan49 as influenced by modified organic materials (Shrimp Shell Powder) in the seedbed and in the main field and found that organic materials application showed non-significant effect to biological yield. Chakrabortty (2013) conducted a field experiment at the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2011 to May 2012 to study the growth and yield of Boro rice as affected by seedling age and planting geometry under System of Rice Intensification (SRI) and reported that seedling age varied biological yield of Boro rice and the maximum biological yield (9.84 tha^{-1}) was recorded in 16 days old seedling and the minimum biological yield (8.73 tha^{-1}) was found in 30 days old seedling. Chandrapala *et al.* (2010) a field experiment conducted during the kharif season of 2007 and 2008 on sandy clay loam soil-having pH 7.65 at Hyderabad. That observed that the transplanting of 12-day old seedling of rice (cv. Rassi) under SRI at a spacing of (25×25cm), was recorded significantly higher biological yield over 25 days seedling under conventional transplanting at (20×15cm) and direct sowing of sprouted rice under un-puddled condition. Luenced biological yield comparable to control treatment.

2.5 Effect of organic materials (shrimp shell powder) application on Seedbed soil

2.5.1 pH of Seedbed soil

Kananont *et al.* (2015) conducted an experiment with Fermented chitin waste (FCW) with three levels of FCW @ (0.25%, 0.50% and 1.0% (w/w)) along with CF = soil supplemented with chemical fertilizer and CMF=soil supplemented with chicken manure fertilizer. The results found that application of FCW to the soil led to an increased pH level (5.0-6.0 approx.) in the soil.

2.5.2 Organic carbon in Seedbed soil

Gooday (1990) stated that chitin and its derivatives show additional properties among carbohydrates, as nitrogen content and, therefore, a low C/N ratio. Manucharova *et al.* (2005 and 2006) observed that its addition increases both prokaryote and eukaryote microbial populations and their activities, since they are altogether involved in chitin mineralization, including populations of nitrogen fixation microorganisms, and methane, carbon dioxide and dinitrogen monoxide emissions are raised. Oka and Pivonia (2003) stated that many of these chitinolytic organisms establish beneficial symbiotic interactions with plants, as mycorrhiza and Rhizobium *spp.*, favoring vegetal absorption of certain nutrients and especially nitrogen fixation. For example, amendments of chitin together with fertilizers as urea have been used to improve soil microbiota, to control pathogenic organisms and to strengthen plant nutrition, all these showing better results than the controls in tomato, carnation and grazing.

2.5.3 Organic matter in Seedbed soil

Kananont *et al.* (2015) conducted an experiment with Fermented chitin waste (FCW) with three levels of FCW @ (0.25%, 0.50% and 1.0% (w/w)) along with CF=soil supplemented with chemical fertilizer and CMF=soil supplemented with chicken manure fertilizer. The results found that application of FCW to the soil led to an increased OM level in the soil. Zhang *et al.* (2009) stated that the combined application of organic manure and chemical fertilizers increased organic matter content in soil.

CHAPTER 3

Materials and Methods

CHAPTER 3
MATERIALS AND METHODS

The experiment was conducted under the net house at Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December 2020 to May 2021 in Boro season. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout of the experimental design, intercultural operations, data recording and their analyses.

3.1 Experimental period

The experiment was conducted during the period from mid December 2020 to May 2021 in *Boro* season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted in the agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental site belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28 (Anon.,1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon.,1988b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh.

3.2.3 Experimental site

The research work was carried out at the experimental field of Sher-e-Bangla Agricultural University, Dhaka. The soil of the experimental plots belonged to the Agro Ecological Zone Madhupur Tract (AEZ-28). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-III.

Plate 1. The Experimental site where the experiments were took place.

3.2.4 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 6.3. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0–15 cm depths were collected from the Sher-e-Bangla Agricultural University (SAU) Farm, field. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physicochemical properties of the soil are presented in below table.

Table 1: Morphological characteristics of the experimental area

Morphological features	Characteristics
Location	SAU soil research field, Dhaka
AEZ	Modhupur Tract-28
General Soil Type	Shallow Red Brown Terrace Soil
Land type	Medium High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Table 2: The initial physical and chemical characteristics of soil used in this expt.

Physical characteristics	
Constituents	**Value**
Sand	25%
Silt	62%
Clay	37%
Textural class	Silty clay loam
Available Sulphur	17 ppm
Available Phosphorus	17.69 ppm
pH	6.4
Organic carbon	0.5%
Organic matter	0.87%

3.2.5 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, and Dhaka and has been presented in (Appendix-IV).

3.3 Experimental materials

BRRI dhan84 and effect of seed priming with salicylic acid and different level of Shrimp shell powder were used as experimental materials for this experiment. The important characteristics of these are mentioned below:

3.3.1 BRRI dhan84

Rice (*Oryza sativa*) variety BRRI dhan84 was used as planting material. BRRI developed this variety and released in 2017. It is the most popular & high yielding *Boro* variety suitable for planted at 15th $-$30th December. This variety attains a height of 96cm. The life cycle of this variety is 140-145 days. Grain yield is around 6.5tha^{-1} and 1000 grain weight is 22.8g. The seeds of this variety were collected from Bangladesh Rice Research Institute (BRRI), Gazipur. The rice haszinc content

27.6mg kg^{-1}, 25.9% amylose content with 9.7% protein content. BRRI dhan84 was released as a high yielding, zinc enriched rice variety to meet the nutritional (zinc) demand of the country.

3.3.2 Salicylic Acid

Salicylic acid is a phenolic derivative, distributed in a wide range of plant species. Salicylic acid is a monohydroxy benzoic acid that is benzoic acid with a hydroxy group at the ortho position. It is a white solid first isolated from the bark of willow trees (*Salix spp*.), from which it gets its name. Salicylic acid is an organic compound with the structural formula $C_6H_4(OH)COOH$. Salicylic acid is a plant hormone. It is colorless, bitter-tasting solid. IUPAC name 2-hydroxy benzoic acid.SA molecular weight is 138.12 g/mol.

3.3.3 Organic Material (Shrimp Shell Powder)

Chitosan is a linear polysaccharide that composed of D-glucosamine (deacetylated unit) and N-acetyl-D-glucosamine (acetylated unit) linked by β-(1-4) glycosidic bonds. Chitosan contains free amine groups ($-NH_2$). Chitosan is made by treating the chitin shells of shrimp. Organic material Shrimp shell powder (SSPd) is prepared from the Crustecean byproducts like crabs shell, shrimp shell, lobster shell etc through the deacetylation process. Whereas, modified organic material is prepared from the sea Shrimp shell powder by-products through sun drying, oven drying, milling, sieving and finally used the powder as the acetylated form having less than two millimetre in size and use the material directly in the main field. The composition of organic material is given below

Table-03: Composition of the organic material (Shrimp Shell Powder) which was used in the research work.

Name of the nutrients	Nutrient content
Nitrogen (N)	9.6 -13%
Phosphorus (P)	0.643 %
Potassium (K)	0.28 %
Sulphur (S)	0.092 %
Calcium (Ca)	2.43 %
Magnesium (Mg)	0.36 %
Zinc (Zn)	92.03 ppm
Boron(B)	152 ppm
Organic Carbon (OC)	13.52%
Organic Matter (OM)	23.41 %
pH	8.7

3.4 Seed Collection and sprouting

BRRI dhan84 was collected from BRRI (Bangladesh Rice Research Institute), Joydebpur, Gazipur. Healthy and disease free seeds were selected, following standard technique. Seeds were immersed in two plastic glasses. One plastic glass contained 50 µM Salicylic acid solution and another plastic glass contained water. Some seeds were immersed in 50µM SA solution and some seed immersed in water at 24 hours for enhance germination (%). These were then taken out of water and 50 µM SA and kept in Plastic glasses. The seeds started sprouting after 48 hrs. Which were suitable for sowing in 72 hrs.

3.5 Experimental treatment

The single factor experiment was conducted with six treatments of Salicylic acid and Shrimp Shell Powder as mentioned below:

T_1 = 0 µM Salicylic Acid + 0 % Shrimp Shell Powder

T_2 = 0 µM Salicylic Acid + 0.25 % Shrimp Shell Powder

T_3 = 0 µM Salicylic Acid + 0.50% Shrimp Shell Powder

T_4 = 50 µM Salicylic Acid + 0 % Shrimp Shell Powder

T_5 = 50 µM Salicylic Acid + 0.25 % Shrimp Shell Powder

T_6 = 50 µM Salicylic Acid + 0.50 % Shrimp Shell Powder

3.6 Sowing and transplanting time

Generally, farmers prepared the seedbed and sow their seed in the seedbed during the month of October to November and transplant seedling in the main filed at the month of November to December. But in this experiment late sowing was done at 15 December 2020 and transplanting at 31 January, 2021 to observe the yield variations between optimum time and the late sowing organic materials treated seedling.

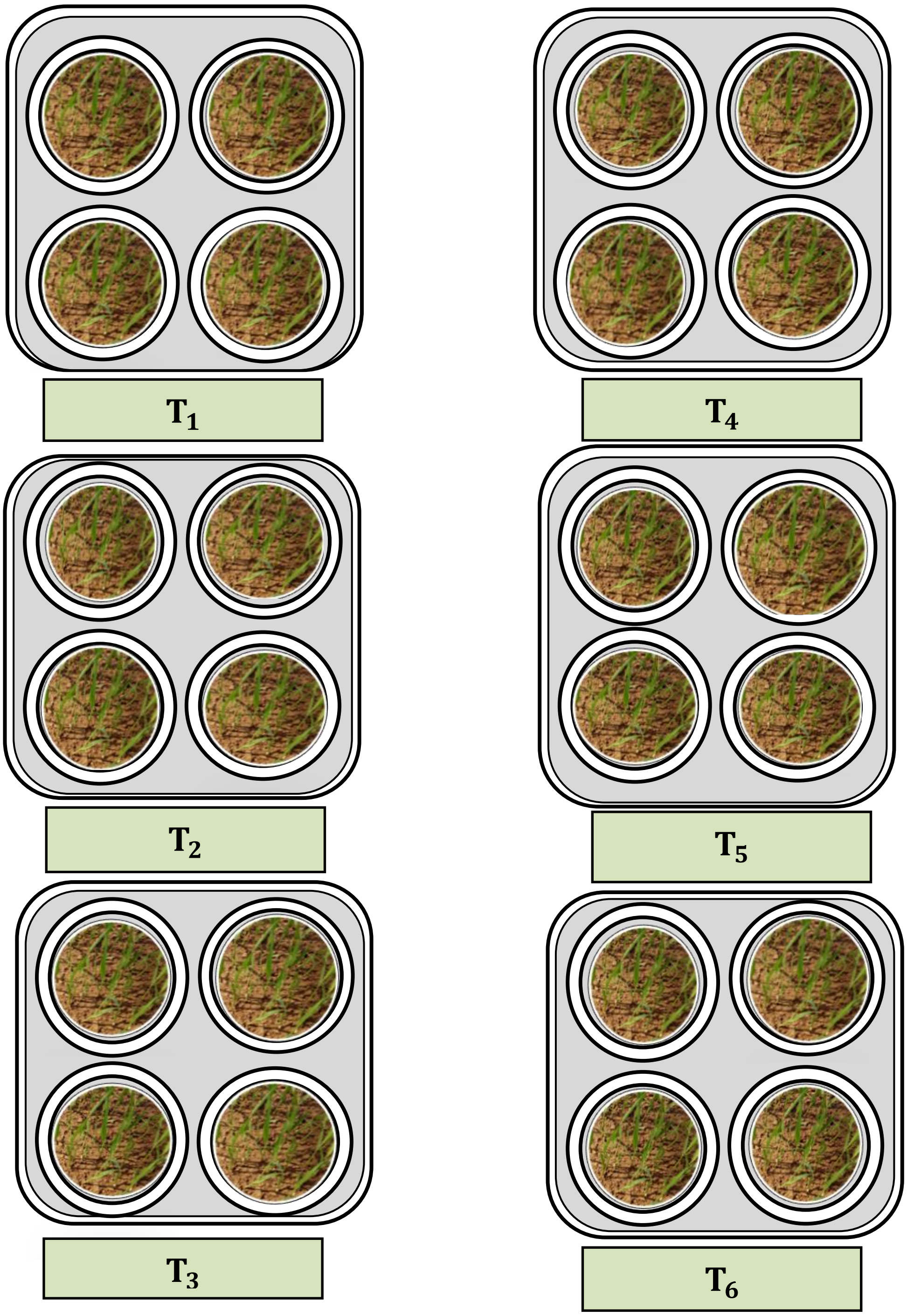
3.7 Seedbed pot preparation and application of shrimp shell powder

Plastic pots were used for raising seedling. Filed moist soil was collected from Sher-e-Bangla Agricultural University farm then mixed with different level of organic materials according with par treatment requirement. Then the pot was filled with organic materials treated soil. After that 50 seeds were sown in the pot for raising seedlings.

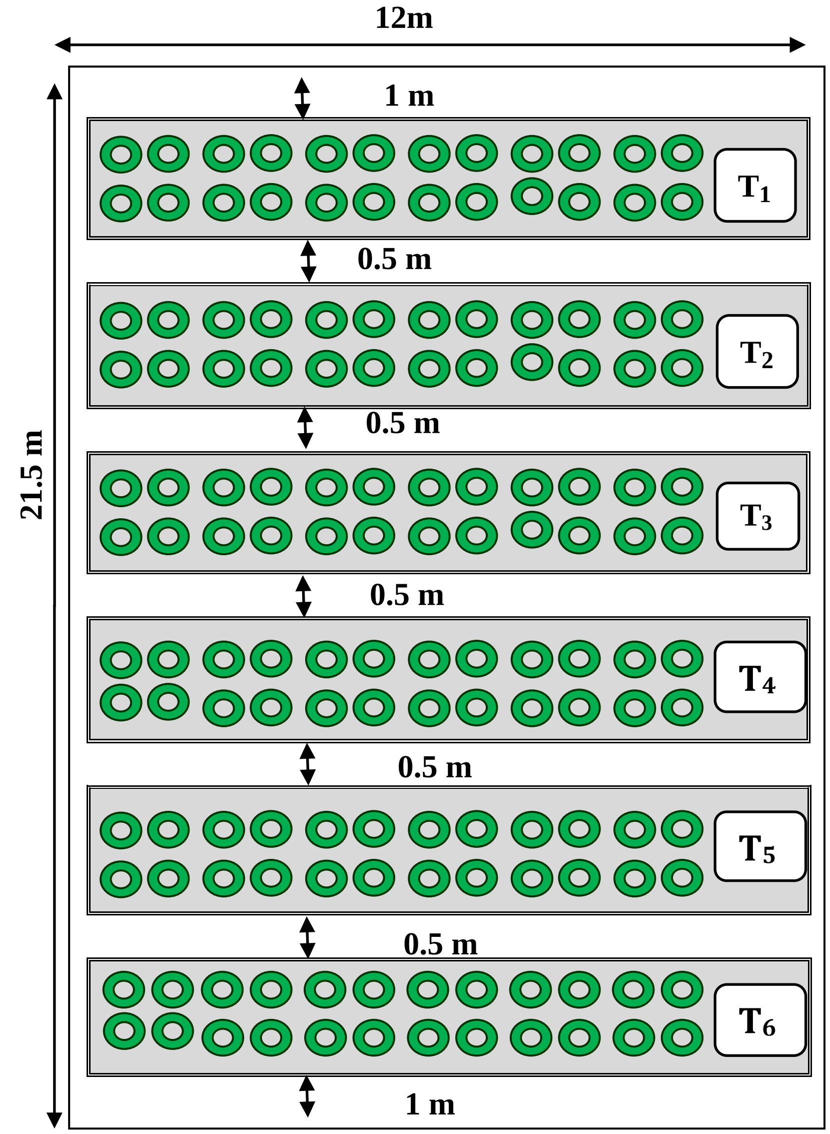
3.8 Experimental design and layout

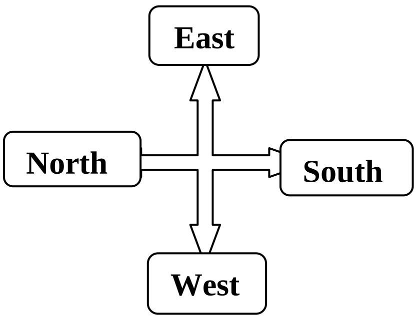
A single factor was laid out in Completely Randomized design (CRD) with six treatments and twenty four replications. Fourteen (14) inches size plastic pots having 10.5inches length and 9.5 inches diameter with a hole at the centre of the bottom were used. Each treatment had 24 pots and total pots in the experimental field were 24×6 = 144 will be made for the experiment with 6 treatments. Each pot will be of required size. The layout of the experiment is given below:

Appendix-I: Layout of Seedbed Pot Experiment:



Appendix-II: Experimental Design and Main Field Layout





Treeatment combination:

T_1 = 0 µM SA + 0 % SSPD
T_2 = 0 µM SA + 0.25% SSPD
T_3 = 0 µM SA + 0.5% SSPD
T_4 = 50 µM SA + 0% SSPD
T_5 = 50 µM SA + 0.25% SSPD
T_6 = 50 µM SA + 0.5% SSPD

3.9 Details of experimental preparation

3.9.1 Selection and preparation of the pot

Earthen pots of having 14inches' diameter, 10.5inches' height with a hole at the centre of the bottom were used. Silty clay loam soil was used in the experiment. The upper edge diameter of the pots was 9.5 inches. While filling with soil, the upper one inch of the pot was kept vacant so that irrigation can be provided using a hose pipe. As such the diameter of the upper soil surface was 15inches' (30 cm) and the area of the upper soil surface was (πr^2 = 3.14× 0.015 × 0.015 = 0.07 m^2). The preparation of the pot was done in 30 December 2021.

3.9.2 Seedling transplanting in the pot

The seedling of rice was transplanted to the pot according to par treatment requirement. Seedling transplanting was done at 31 January, 2021. One seedling was transplanted in each pot.

3.10 Fertilizer application

All the fertilizers including 1/3rd dose of urea were added to the soil during final land preparation on 31 January, 2021. Urea was applied equally in three splits. The second split (1/3rd of total amount of N) was applied on 15th February, 2021 and the third split (1/3rd of total amount of N) on 5th March, 2021 at maximum tillering stage.

3.11 Transplanting of seedling

Twenty one days old seedlings were uprooted carefully from the seedbed pot and transplanted in the experimental pots on 31 January, 2021. Single seedling was transplanted in each hill.

3.12 Intercultural operations

Intercultural operations were done for ensuring and maintaining the normal growth of the crop. The detailed intercultural operations were recorded in the (Table 4).

3.12.1 Application of irrigation water

Irrigation water was added to each pot according to the critical stage. It was given by using water pipe.

3.12.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Three hand weeding were done to reduce crop competition with weed. First weeding was done at 20 days after transplanting followed by second weeding at 15 days after first weeding. Third weeding was done 15 days after second weeding.

3.12.3 Protection against insect and pest

There were some incidence in insects specially rice leaf borer. which were controlled by spraying Diazinon 50 EC. Crop was protected from birds and rats during the grain filling period. Rat was controlled by using field trap and poisonous bait. The net house was kept under strong surveillance, especially during morning and afternoon to control birds. Application of insecticide was applied at 1 January 2020. Crop was protected from birds during the grain filling period by using net and covering the experimental site.

3.13 Harvest and Threshing

The crop was harvested depending upon the maturity of plant. Harvesting was done by serrated edged sickles manually from each pot. Maturity of crop was determined when 80% of the grains became matured. The harvested crops from each pot were bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done plot wise by hand. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields per pot were determined and expressed in gram (g).

Table 4: Dates of different operations done during the field study

Operations	Working Dates
Collection of field moist soil	10 December 2020
Different level of Shrimp Shell powder was mixed with field moist soil	14 December 2020
Filling the pot with Shrimp Shell powder mixed soil	14 December 2020
Seed sowing	15 December 2020
Collection and preparation of the main pot	30 December 2020
Application of fertilizers (1/3rd Urea, TSP, MoP, Gypsum)	31 January 2021
Transplanting of seedlings	31 January 2021
Intercultural Operations	**Working Dates**
1st Weeding	20January 2020
2nd Weeding	4 February 2020
3rd Weeding	20February 2020
1st split application of urea	31 January 2020
2nd split application of urea	15 February 2021
3rd split application of urea	5 March 2021
Insecticide application	22 March 2021
Harvesting and threshing	6 May and 8 May 2021

3.14 Data collection

The data were recorded on the following parameters

i. Average seedling height (cm)
ii. Fresh weight (g)
iii. Oven dry weight (g)
iv. Seedling strength (mg cm^{-1})
v. Number of tillers $hill^{-1}$
vi. Number of effective tillers $hill^{-1}$
vii. Days to first flowering
viii. Grain yield (g pot^{-1})
ix. Straw yield (g pot^{-1})
x. Biological yield (g pot^{-1})

3.15 Procedure of data collection

i. Average seedling height (cm)

The heights of 25 seedlings during transplanting time were measured with a meter scale from the ground level to tip of seedlings and the mean heights were expressed in cm.

ii. Fresh weight $\mathbf{seedling}^{-1}$(mg)

Fresh weight of 25 seedlings were collected during transplanting time from each treatment and then weighted by using a digital electric balance and the mean weight were expressed in mg.

iii. Oven dry weight $\mathbf{seedling}^{-1}$(mg)

Different treated 25 seedlings were collected from seedbed and then sun dried. The sun dried seedling again dried in oven and weighted by using a digital electric balance & their mean was expressed in mg

iv. Seedling strength (mg $\mathbf{cm}^{-1}$)

Seedling strength was measured by using the following formula

$$\text{Seedling strength} = \frac{\text{Oven dry weight per seedling}}{\text{Average seedling height}}\ \text{mg/cm}$$

v. Number of tillers pot $^{-1}$

Number of tillerspot $^{-1}$ were counted at 10 days' interval up to 60 DAT from pre-selected hills and finally averaged as their numberpot $^{-1}$. Only those tillers having three or more leaves were considered for counting.

vi. Number of effective tillers pot $^{-1}$

The total number of effective tillers pot $^{-1}$ were counted as the number of panicle bearing tillers per hill. Data on effective tiller per pot were recorded at harvesting time and average value was recorded.

vii. Days to first flowering

The date of flower blooming was recorded from the number of days of 1st the date 31th march, 2021 of flower blooming after transplanting.

xii. Grain yield (gpot $^{-1}$)

Grain yield from each pot were taken expressed as gpot $^{-1}$ on about 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

xiii. Straw yield (gpot $^{-1}$)

After separating the grains, straw obtained from each pot were sun dried and weighed carefully by digital electrical balance and finally converted to gpot $^{-1}$.

xiv) Biological yield (gpot $^{-1}$)

The summation of grain yield and above ground straw yield was the biological yield. Biological yield pot $^{-1}$ (g) = (Grain yieldpot $^{-1}$+ straw yieldpot $^{-1}$) g.

3.16 Chemical analysis of post transplanted seedbed soil properties

3.16.1 Particle size analysis

Particle size analysis of soil was done by Hydrometer Method and then textural class was determined by plotting the values for 25 % sand, 62% silt and 37% clay to the "MarshalL-1s Textural Triangular Coordinate" according to the USDA system.

3.16.2 Soil pH

Soil pH was measured with the help of a Glass electrode pH meter using soil and water at the ratio of 1:2.5 as described by Jackson (1962).

3.16.3 Organic C

Organic carbon in soil was determined by Walkley and Black (1934) Wet Oxidation Method. The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed as percentage.

3.16.4 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured calorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve. Method name is Spectrophotometric Molybdovanadate Method (Boltz, D.F., and Mellon, M.G.1948)

3.16.5 Available Sulphur

Available sulphur in soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution (Page *et al.*,1982). The S content in the extract was determined turbimetrically and the intensity of turbid was measured by Spectrophotometer at 420 nm wave length. Method name is Spectrophotometric Method (Jones, A.S., and Letham, D.S. 1956)

3.16.6 Chemical analysis of soil sample

Soil samples were analyzed for both physical and chemical properties in the laboratory of Department of Soil Science of Sher-e-Bangla Agricultural University, Dhaka-1207. The properties studied included texture, pH, organic matter etc. The physical and chemical properties of initial soil have been presented in (Table-2). The soil was analyzed following standard methods: Particle-size analysis of soil was done by Hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values for 25% sand, 62% silt and 37% clay to the "Marshall"s Textural triangular coordinate" following the USDA system. Soil pH was measured with the help of a glass electrode pH meter using soil suspension of 1:2.5 as described by Jackson (1962). Organic carbon in soil was determined by wet oxidation method of Walkley and Black (1934). The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed in percentage.

3.17 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique and the mean differences were adjudged by LSD test using the statistical computer package program, Statistix10.

CHAPTER 4

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

Results obtained from the present study have been presented and discussed in this chapter with a view to study the improvement of *Boro* seedling by application of organic material (Shrimp Shell Powder) & Salicylic acid. To demonstrate, the effect of 50µM salicylic acid to enhance the germination of variety (BRRI dhan84). Shrimp shell powder has been applied in different doses to look at the yield contributing character. The data are given in different tables and figures. The results have been discussed and possible interpretations are given under the following headings.

4.1 Seedling Germination (%)

Seedling germination percentage of BRRI dhan84 showed significant variation with the application of organic material (Shrimp Shell Powder) in all the treatments used in the experiment. The experimental results revealed that maximum seedling germination percentage (79%) was observed in T_6 (50 µM Salicylic Acid + 0.50 % Shrimp Shell Powder) treatment and followed by T_5 (50 µM Salicylic Acid + 0.25 % Shrimp Shell Powder) germination percentage (75%), T_2 (0 µM Salicylic Acid + 0.25 % Shrimp Shell Powder) germination percentage (73%), T_3 (0 µM Salicylic Acid + 0.50% Shrimp Shell Powder) germination percentage (69%), T_4 (50 µM Salicylic Acid + 0 % Shrimp Shell Powder) germination percentage (67%), Whereas minimum seedling germinations percentage (62%) was observed in treatment T_1 (0 µM Salicylic Acid + 0 % Shrimp Shell Powder) (control) (Fig.1.3). Seedling germination was increased almost in a dose dependent manner. Present findings were supported with the similar findings of Rahman *et al.*, (2015); Ahmed *et al*., (2020) and Sultana *et al*., (2020). Salicylic acid can affect seed germination, cell growth, expretion of genes associated with senescence and fruit production (Klessing *et al.,* 2018; Kawano *et al.,* 2013). The experimental results is highly significant of seedling germination percentage in T_4 (50 µM Salicylic Acid + 0 % Shrimp Shell Powder) germination percentage (67%), (Fig-1.1).

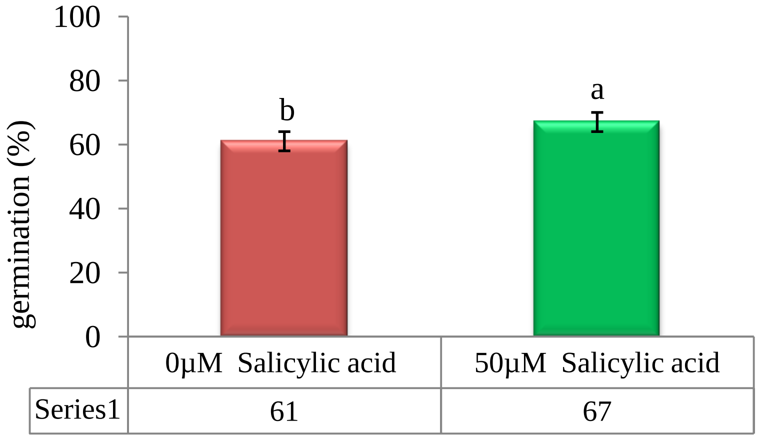


Fig-1.1: Effect of seed priming with salicylic acid on germination (%) of BRRI dhan84.

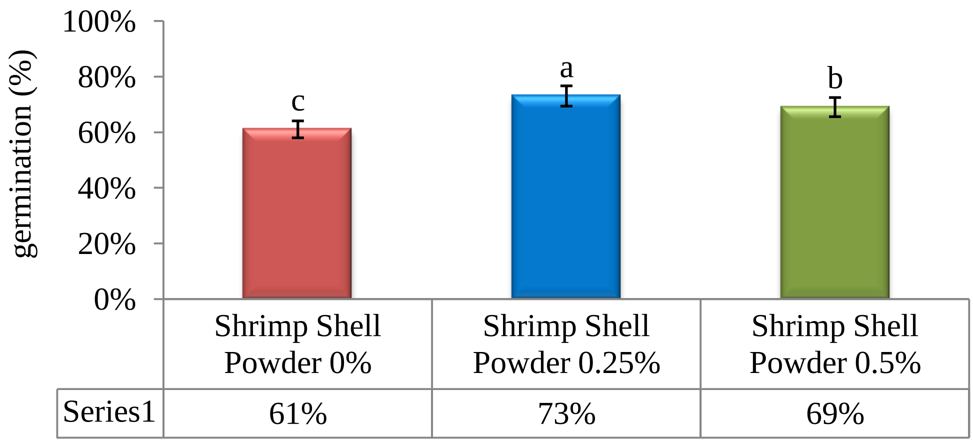


Fig-1.2: Effect of different doses of Shrimp shell powder (0% SSPd, 0.25% SSPd and 0.5% SSPd) on germination (%) of BRRI dhan84

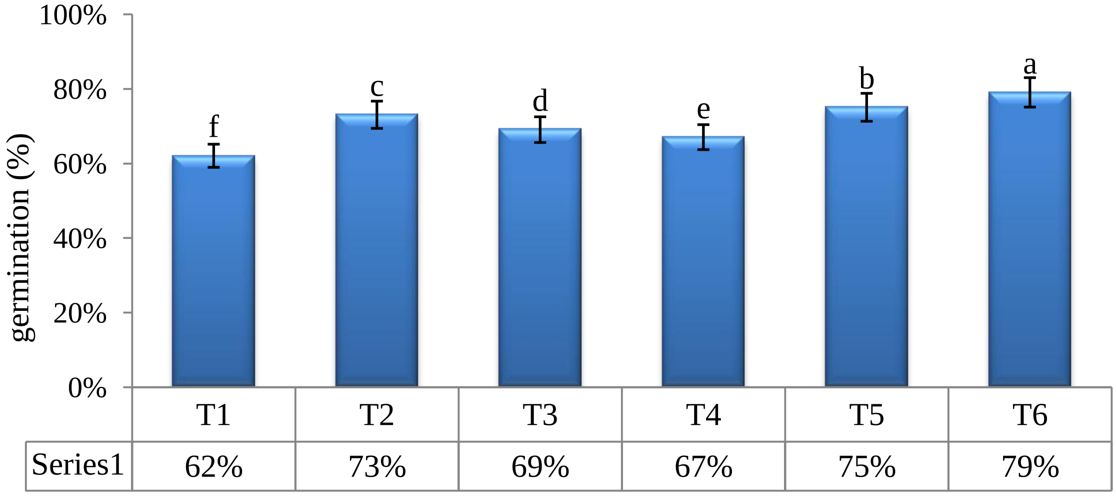


Fig-1.3 Effect of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the germination percentage (%) of BRRI dhan84. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1 = 0 µM SA + 0 % SSPd T_2 = 0 µM SA + 0.25 % SSPd T_3 = 0 µM SA + 0.5% SSPd
T_4 = 50µM SA + 0 % SSPd T_5 = 50µM SA + 0.25 % SSPd T_6 = 50µM SA + 0.5 % SSPd

4.2 Seedling fresh weight (mg)

Seedling fresh weight was scientifically affected by application of Shrimp Shell Powder of BRRI dhan84 (Figure-2.3). Experimental result showed that, the maximum fresh weight (593.29mg) was obtained in T_6 (50 µM Salicylic acid + 0.5 % Shrimp Shell Powder) treatment, whereas the minimum fresh weight (239.67mg) was observed in T_1 (0µM Salicylic acid + 0 % Shrimp Shell Powder) treatment (control). Optimum dose of Shrimp Shell Powder influences the nutrient uptake which improves the growth and development of the plant result in increasing fresh weight seedling^{-1} comparable to higher level of organic material application. Ahmed *et al*. (2020) reported that seedling fresh weight was increased with the application of organic material (Shrimp Shell powder) in the seedbed. Issak and Sultana (2017) also reported that, fresh weight productions of BRRI dhan29 rice seedlings were influenced by the organic material (Shrimp Shell powder) treatments and this might be due its supplementation of plant nutrients and growth regulators.

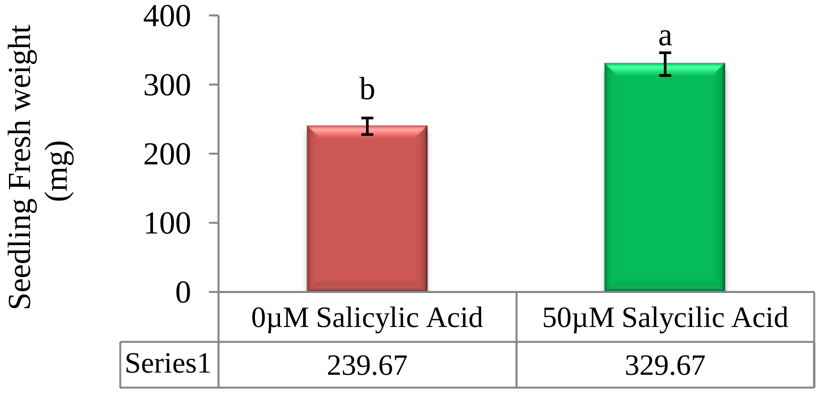


Fig-2.1: Effect of seed priming with salicylic acid on seedling fresh weight (mg) of BRRI dhan84

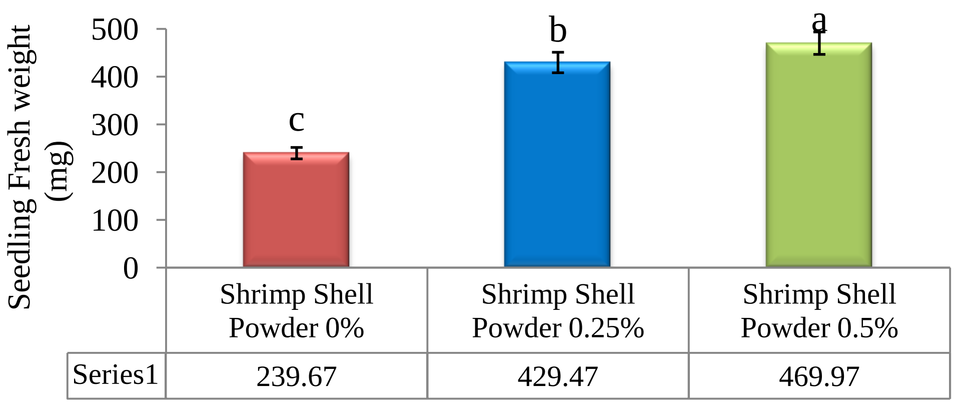


Fig-2.2: Effect of different doses of Shrimp shell powder (0% SSPd, 0.25% SSPd and 0.5% SSPd) on seedling fresh weight (mg) of BRRI dhan84

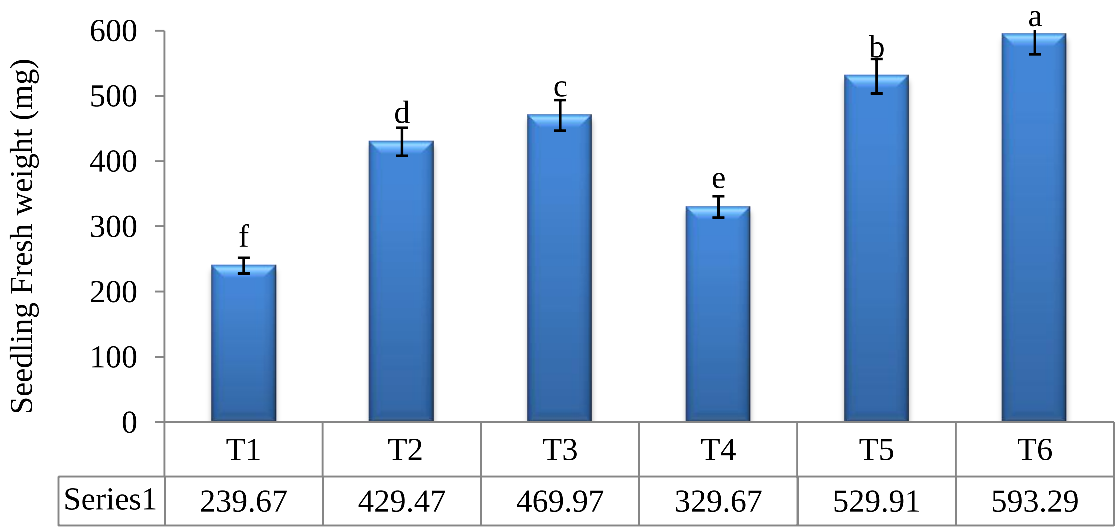


Fig. 2.3: Effect of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the seedling fresh weight (mg) of BRRI dhan84. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1 = 0 µM SA + 0 % SSPd T_2 = 0 µM SA + 0.25 % SSPd T_3 = 0 µM SA + 0.5% SSPd
T_4 = 50µM SA + 0 % SSPd T_5 = 50µM SA + 0.25 % SSPd T_6 = 50µM SA + 0.5 % SSPd

4.3 Seedling oven dry weight (mg)

Application of different level of organic material (Shrimp Shell powder) significantly effects on oven dry weight of BRRI dhan84 (Fig-.3.3). Experimental result showed that, the maximum seedling oven dry weight (396.14mg) was obtained in T_6 (50 µM Salicylic acid + 0.5 % Shrimp Shell powder) treatment, whereas the minimum seedling oven dry weight (144.84 mg) was obtained in T_1 (0 µM Salicylic acid + 0 % Shrimp Shell powder) treatment which was statistically similar with (175.06 mg) T_4 (50 µM Salicylic acid + 0 % Shrimp Shell powder) treatment. Application of organic material (Shrimp Shell powder) influences the nutrient uptake capacity of plant which improve the growth and development of the plant. As a result, increasing seedling oven dry weight comparable to control treatment were noticeable. Ahmed *et al*. (2020) reported that seedling oven dry weight was increased with the application of organic material in the seedbed. Issak and Sultana (2017) also reported that oven dry weight productions of BRRI dhan29 rice seedlings were influenced by the organic material applications and this might be due its nutritional support to the seedlings, improvement of growth promoting hormonal activity and could improve the biological as well as physio-chemical properties of the seedbed soils. Boonlertnirun *et al*. (2008) found that application of organic material stimulates the seedling dry matter weight significantly.

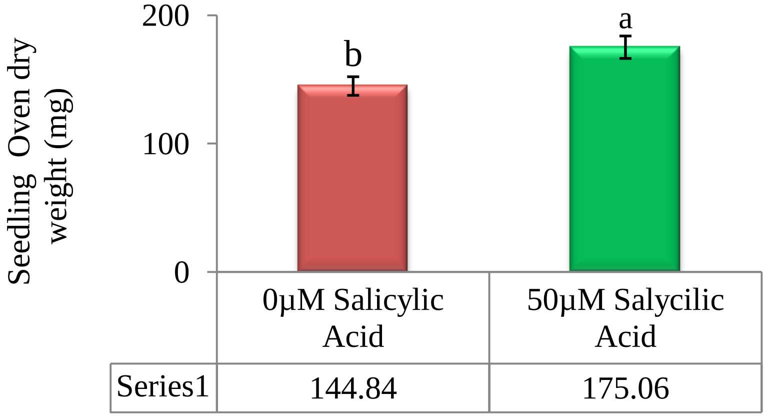


Fig-3.1: Effect of seed priming with salicylic acid on seedling oven dry weight (mg) of BRRI dhan84

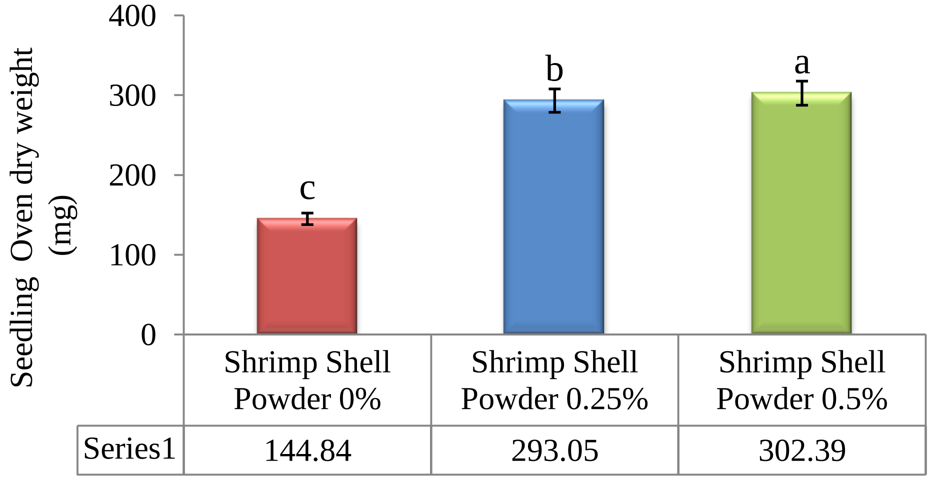


Fig-3.2: Effect of different doses of shrimp shell powder (0% SSPd, 0.25% SSPd and 0.5% SSPd) on seedling oven dry weight (mg) of BRRI dhan84

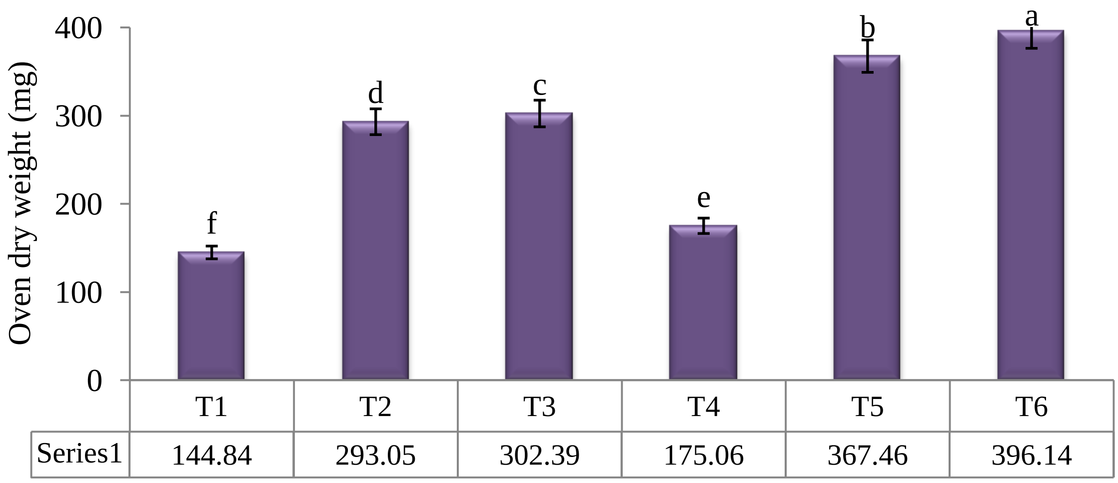


Fig.-3.3: Effect of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the seedling oven dry weight (mg) of BRRI dhan84. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1 = 0 µM SA + 0 % SSPd T_2 = 0 µM SA + 0.25 % SSPd T_3 = 0 µM SA + 0.5% SSPd
T_4 = 50µM SA + 0 % SSPd T_5 = 50µM SA + 0.25 % SSPd T_6 = 50µM SA + 0.5 % SSPd

4.4 Seedling height (cm)

Seedling treated with different level of organic material (Shrimp Shell powder) significantly influenced average seedling height of BRRI dhan84 (Fig-4.3). Experimental result revealed that the maximum average seedling height (24.65cm) was obtained in T_6 (50 µM Salicylic acid + 0.5 % Shrimp Shell Powder) treatment whereas the minimum average seedling height (19.52cm) was obtained in T_1 (0 µM Salicylic acid + 0% Shrimp Shell Powder) treatment, which was statistically similar with (19.84cm) T_3 (0 µM Salicylic acid + 0.5% Shrimp Shell Powder) treatment. The observed growth improvement by Shrimp Shell powder could also be related to the incorporation of nutrients from this powder. The result obtained from the present study was similar with the findings of Ahmed *et al*. (2020) and they reported that seedling height was increased with the application of organic material (Shrimp Shell powder) in the seedbed. Issak and Sultana (2017) found that Boro rice seedlings production was improved by using the organic material (Shrimp Shell powder) in the seedbed. Boonlertnirun *et al.* (2008) also reported that, organic material is a natural biopolymer which stimulates growth and increases yield of plants as well as induces the immune system of plants.

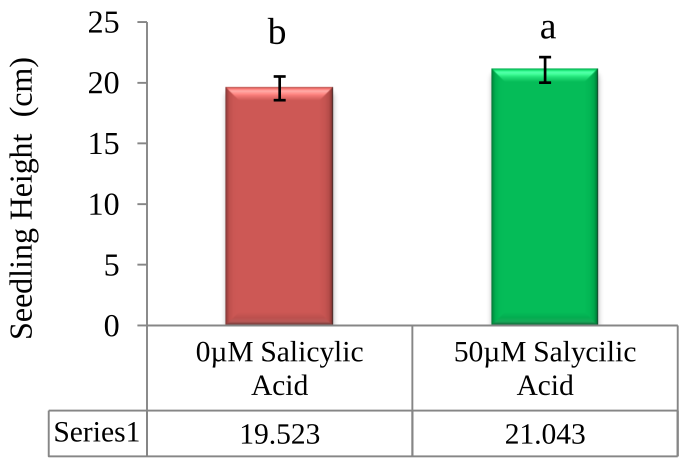


Fig-4.1: Effect of seed priming with salicylic acid on seedling height (cm) of BRRI dhan84

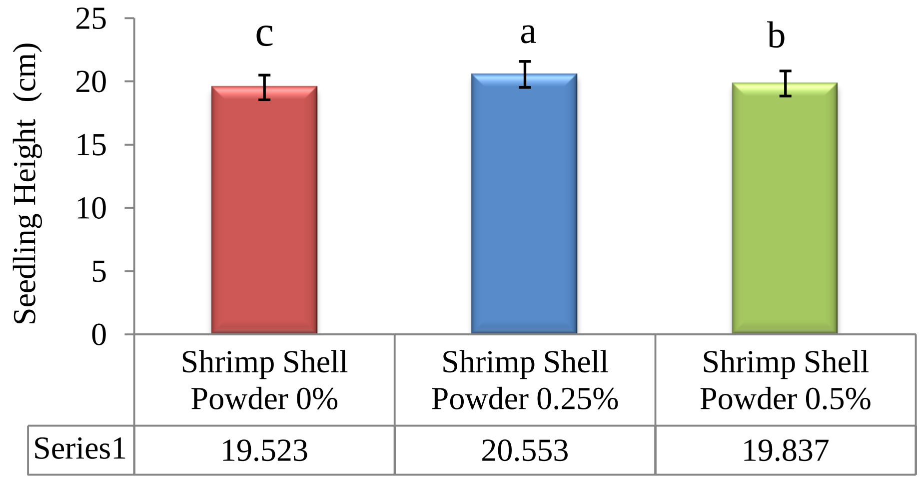


Fig-4.2: Effect of different doses of shrimp shell powder (0% SSPd, 0.25% SSPd and 0.5% SSPd) on seedling height (cm) of BRRI dhan84

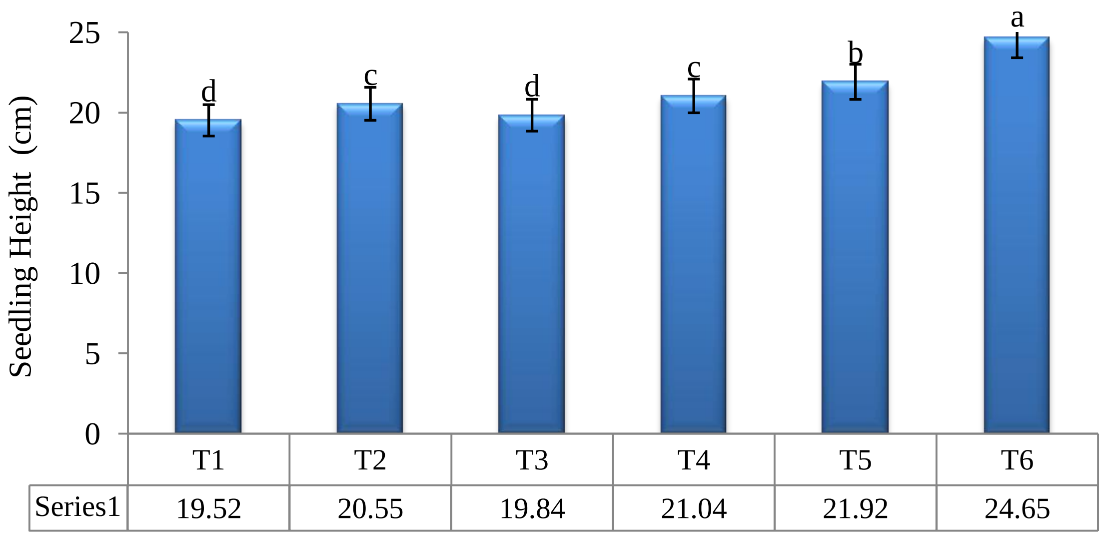


Fig-4.3 Effect of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the seedling height of BRRI dhan84. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1 = 0 µM SA + 0 % SSPd T_2 = 0 µM SA + 0.25 % SSPd T_3 = 0 µM SA + 0.5% SSPd
T_4 = 50µM SA + 0 % SSPd T_5 = 50µM SA + 0.25 % SSPd T_6 = 50µM SA + 0.5 % SSPd

4.5 Seedling strength (mg cm^{-1})

Seedling treated with different level of organic material (Shrimp Shell powder) significantly effect on seedling strength (mg cm^{-1}) of BRRI dhan84 (Figure-5.3). Experimental result showed that, maximum seedling strength (18.08mg cm^{-1}) was obtained in T_6 (50 µM Salicylic acid + 0.5% Shrimp Shell Powder) treatment, whereas the minimum seedling strength (7.42mg cm^{-1}) was obtained in T_1 (0 µM Salicylic acid + 0 % Shrimp Shell Powder) treatment which was statistically similar with (8.32mg cm^{-1}) T_4 (50 µM Salicylic acid + 0 % Shrimp Shell Powder) treatment. Ahmed *et al*. (2020) reported that seedling strength was increased with the application of organic material (Shrimp Shell powder) in the seedbed. Boonlertnirun *et al.* (2008) found that application of chitosan stimulates the seedling strength significantly.

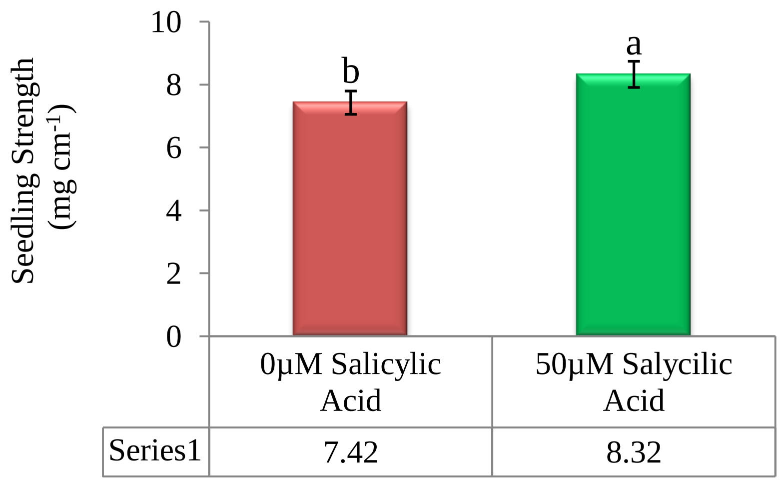


Fig-5.1: Effect of seed priming with salicylic acid on Seedling Strength (mg cm^{-1}) of BRRI dhan84

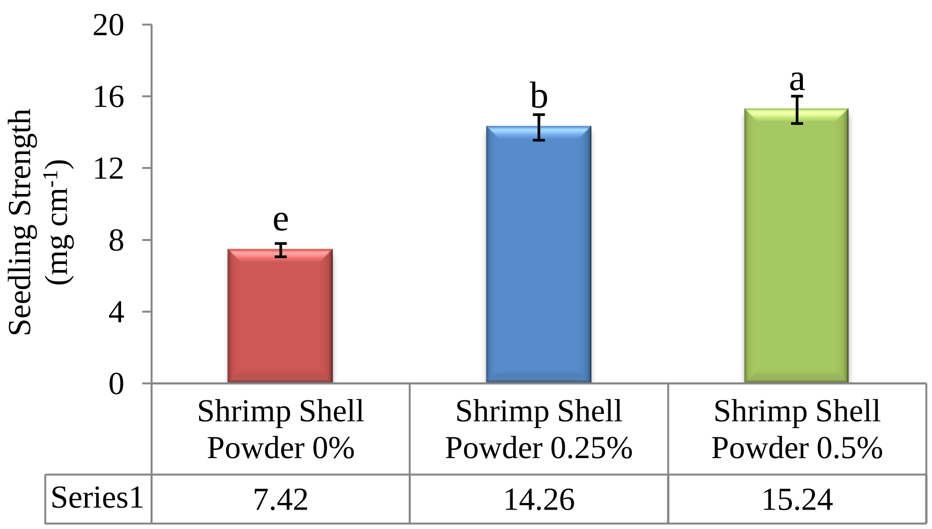


Fig-5.2: Effect of different doses of shrimp shell powder (0% SSPd, 0.25% SSPd and 0.5% SSPd) on seedling strength (mg cm^{-1}) of BRRI dhan84

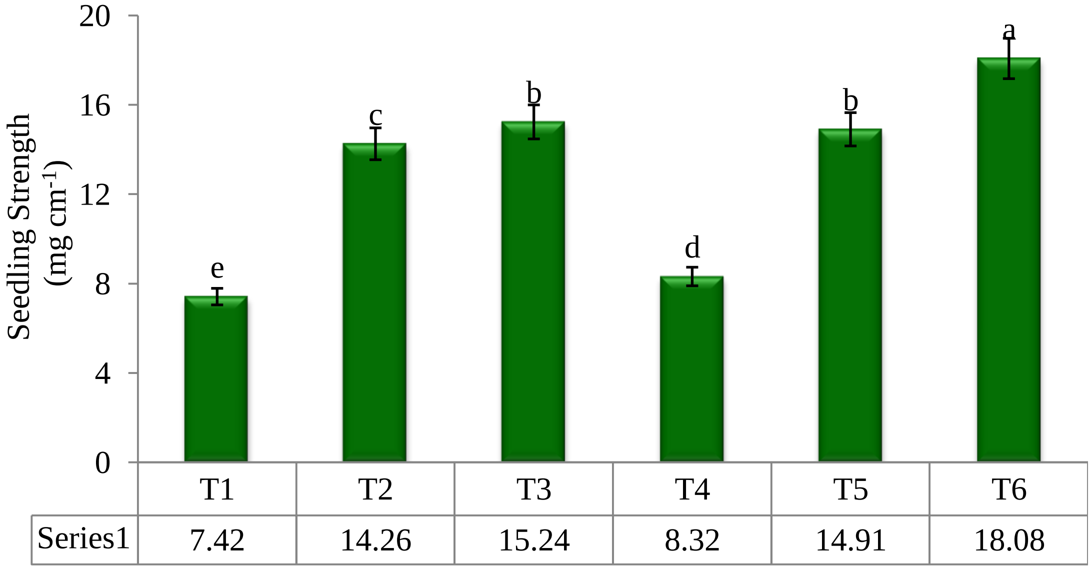


Fig-5.3. Effect of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the seedling strength (mg cm^{-1}) of BRRI dhan84. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1 = 0 µM SA + 0 % SSPd T_2 = 0 µM SA + 0.25 % SSPd T_3 = 0 µM SA + 0.5% SSPd
T_4 = 50µM SA + 0 % SSPd T_5 = 50µM SA + 0.25 % SSPd T_6 = 50µM SA + 0.5 % SSPd

4.6 Effective tillers pot^{-1}

Seedling treated with different level of organic material (Shrimp Shell powder) significantly effect on effective tillers pot^{-1} of BRRI dhan84 (Fig-6.3) . Experimental result showed that, maximum effective hill^{-1} (11.56) was obtained in T_6 (50 µM Salicylic acid + 0.5% Shrimp Shell powder) treatment, whereas the minimum effective tillers hill^{-1} (7.83) was obtained in T_1 (0 µM Salicylic acid + 0 % Shrimp Shell powder) treatment (Control). Ahmed *et al*. (2020) reported that different level of organic material significantly effects on effective tillers hill^{-1} and the second highest number of effective tillers hill^{-1} (11.46) was obtained in the T_5 treatment whereas the lowest number of effective tillers hill^{-1} (7.83) was obtained in the T_1 (control) treatment. It was observed that the application of organic material (Shrimp Shell powder) in soil increased the effective tillershill^{-1}. Boonlertnirun *et al.* (2012) also showed that application methods of organic material significantly affected tiller number per plant.

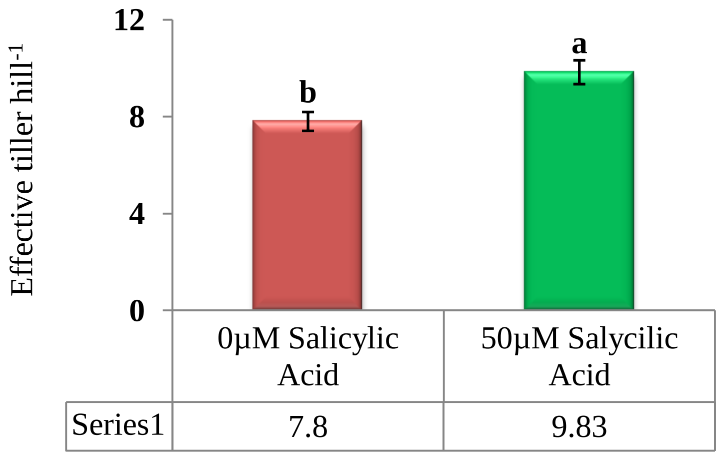


Fig-6.1: Effect of seed priming with salicylic acid on number of effective tiller hill^{-1} of BRRI dhan84

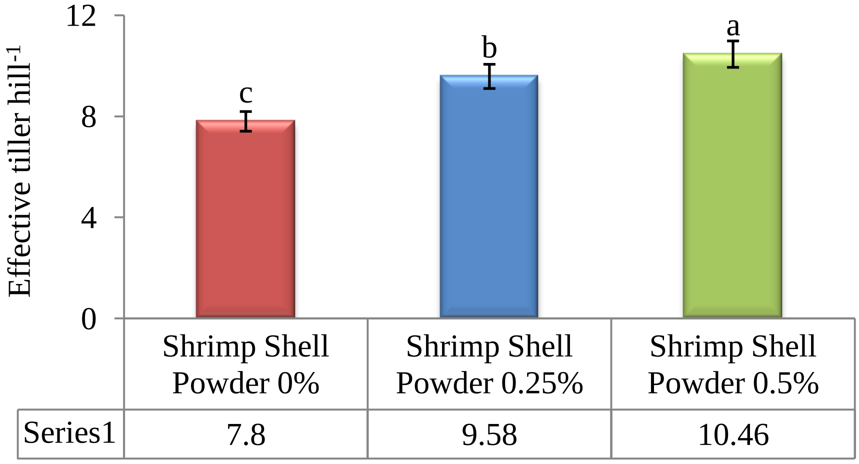


Fig-6.2: Effect of different doses of shrimp shell powder (0% SSPd, 0.25% SSPd and 0.5% SSPd) on number of effective tiller hill^{-1} of BRRI dhan84

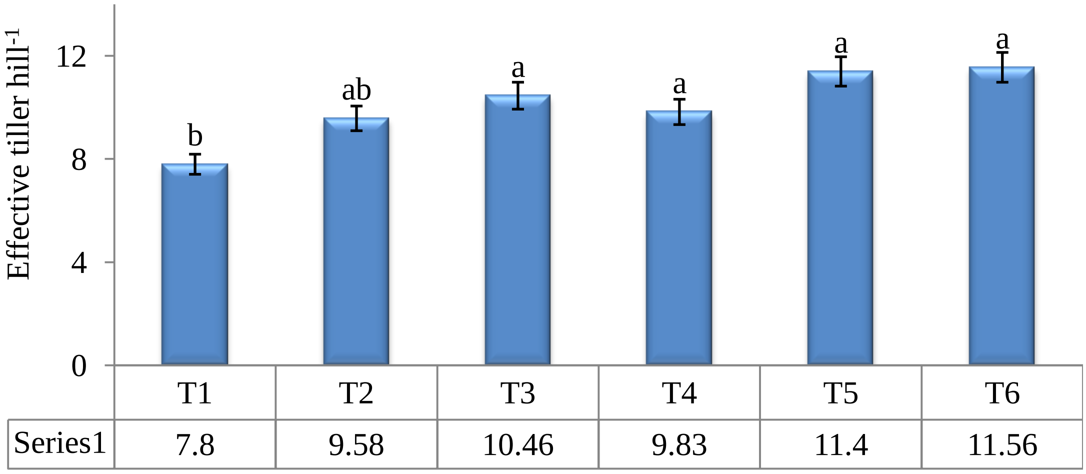


Fig.-6.3 Effect of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the number of effective tiller hill^{-1} BRRI dhan84. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD. 7.8 9.58 10.46

T_1 = 0 µM SA + 0 % SSPd T_2 = 0 µM SA + 0.25 % SSPd T_3 = 0 µM SA + 0.5 % SSPd
T_4 = 50µM SA + 0 % SSPd T_5 = 50µM SA + 0.25 % SSPd T_6 = 50µM SA + 0.5 % SSPd

4.7 Grain yield sundry weight($gpot^{-1}$)

Figure-7.3, Shows the effects of different treatments on grain yield **s**undry weight. Grain yield sundry weight **(** $gpot^{-1}$) was significantly influenced by the shrimp shell powder treatment. Grain yield sundry weight was increased due to the shrimp shell powder treatment compare to the control treatment. The highest grain yield sundry weight (66.35 $gpot^{-1}$) was obtained in the T_6 (50 µM Salicylic acid + 0.5 % Shrimp shell powder) treatment which was significantly greater than that obtained in the (49.59 $gpot^{-1}$) T_1 control (0 µM Salicylic acid + 0 % Shrimp shell powder) and T_5 treatment (50 µM Salicylic acid + 0.25 Shrimp shell powder) was (60.82 $gpot^{-1}$) and T_4 (50 µM Salicylic acid + 0 % Shrimp shell powder) was (57.02 $gpot^{-1}$) and T_3 (0 µM Salicylic acid + 0.5 % Shrimp shell powder) was (56.01 $gpot^{-1}$) and T_2 (0 µM Salicylic acid + 0.25 % Shrimp shell powder) was (54.12 $gpot^{-1}$) and statistically identical to T_6 (50 µM Salicylic acid + 0.5 % Shrimp shell powder) treatment. Otherwise, The lowest grain yield sundry weight (49.59 $gpot^{-1}$) was obtained in the T_1 treatment (0 µM Salicylic acid + 0 % Shrimp shell powder) control. In terms of grain yield sundry weight **(** $gpot^{-1}$) the treatments may be arranged as $T_6 > T_5 > T_4 > T_3 > T_2 > T_1$. It was observed that, as the rate of shrimp shell powder application in soil increases grain yield sundry weight **(** $gpot^{-1}$) also increases.

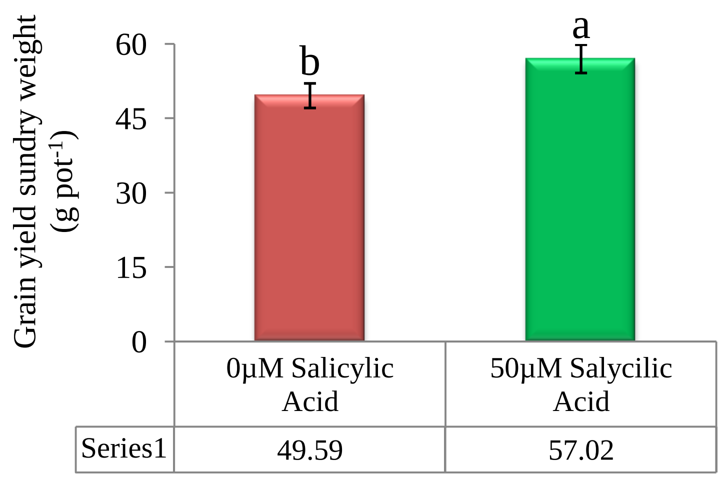
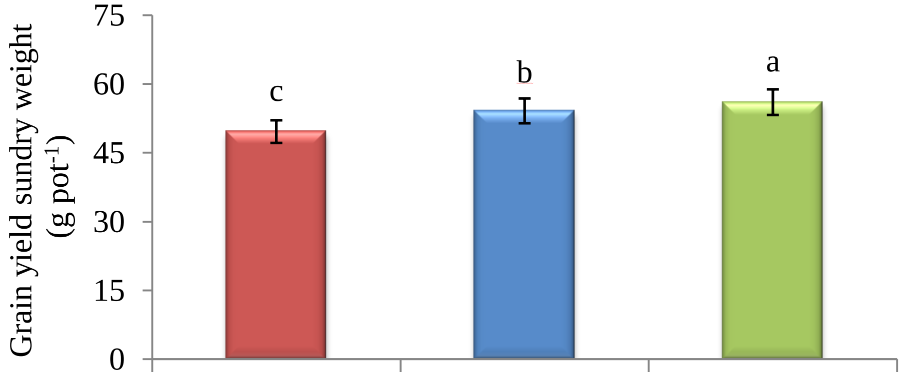
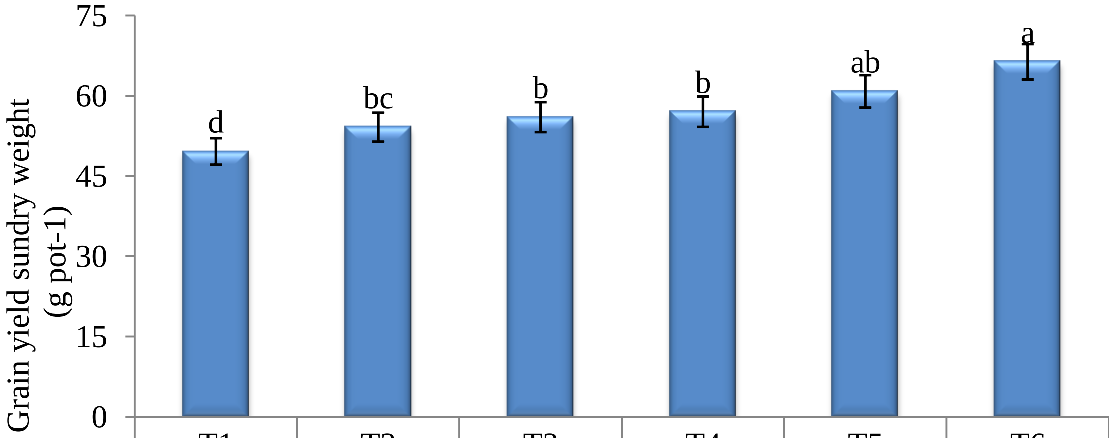


Fig-7.1: Effect of seed priming with salicylic acid on grain yield sundry weight **(** $gpot^{-1}$) of BRRI dhan84



	Shrimp Shell Powder 0%	Shrimp Shell Powder 0.25%	Shrimp Shell Powder 0.5%
Series1	49.59	54.12	56.01

Fig-7.2: Effect of different doses of shrimp shell powder (0% SSPd, 0.25% SSPd and 0.5% SSPd) on grain yield sundry weight ($gpot^{-1}$) of BRRI dhan84



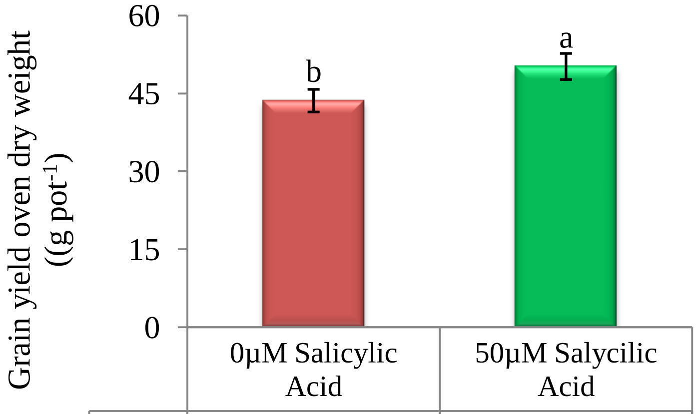
	T1	T2	T3	T4	T5	T6
Series1	49.59	54.12	56.01	57.02	60.82	66.35

Fig.7.3: Effect of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the grain yield sundry weight ($gpot^{-1}$) of BRRI dhan84. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1 = 0 µM SA + 0 % SSPd T_2 = 0 µM SA + 0.25 % SSPd T_3 = 0 µM SA + 0.5% SSPd
T_4 = 50µM SA + 0 % SSPd T_5 = 50µM SA + 0.25 % SSPd T_6 = 50µM SA + 0.5 % SSPd

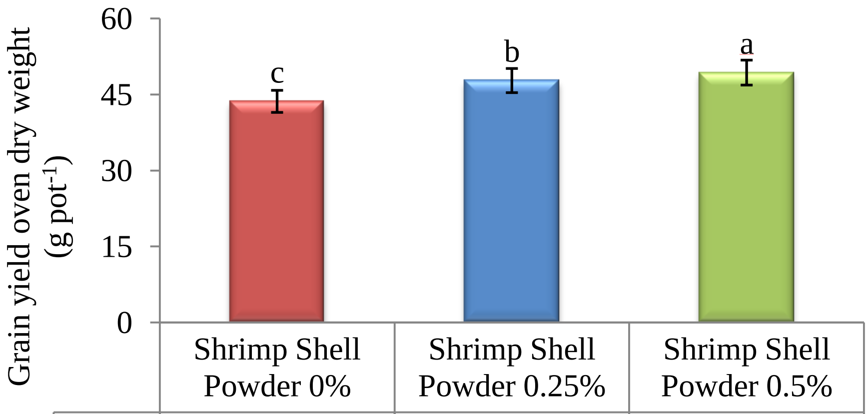
4.8 Grain yield oven dry weight($gpot^{-1}$)

The effects of different treatments on grain yield oven dry weight were significantly influenced by the Shrimp shell powder (Fig-8.3). Grain yield oven dry weight ($g\,pot^{-1}$) was increased due to the shrimp shell powder treatment compare to the control treatment. The highest grain yield oven dry weight ($58.17\,g\,pot^{-1}$) was obtained in the T_6 (50 µM Salicylic acid + 0.5 % Shrimp shell powder) treatment which was significantly greater than that obtained in the ($43.61\,g\,pot^{-1}$) T_1 control (0 μM Salicylic acid + 0 % Shrimp shell powder) and (53.56g pot^{-1}) T_5 treatment (50 μM Salicylic acid + 0.25 % Shrimp shell powder) and (50.19g pot^{-1}) T_4 treatment (50 μM Salicylic acid + 0 % Shrimp shell powder) and (49.29g pot^{-1}) T_3 treatment (0 μM Salicylic acid + 0.5 % Shrimp shell powder) and (47.72g pot^{-1}) T_2 treatment (0 μM Salicylic acid + 0.25 % Shrimp shell powder) and statistically identical to T_6 (50 μM Salicylic acid + 0.5 % Shrimp shell powder) treatment. Otherwise, The lowest grain yield oven dry weight (43.61g pot^{-1}) was obtained in the T_1 (0 μM Salicylic acid + 0 % Shrimp shell powder) control treatment. In terms of grain yield oven dry weight (g pot^{-1}) the treatments may be arranged as $T_6>T_5>T_4 > T_3>T_2>T_1$. It was observed that, as the rate of Shrimp shell powder application in soil increases grain yield oven dry weight (g pot^{-1}) also increases.



	0μM Salicylic Acid	50μM Salycilic Acid
Series1	43.61	50.19

Fig-8.1: Effect of seed priming with salicylic acid on grain yield oven dry weight (g pot^{-1}) of BRRI dhan84



	Shrimp Shell Powder 0%	Shrimp Shell Powder 0.25%	Shrimp Shell Powder 0.5%
Series1	43.61	47.72	49.29

Fig-8.2: Effect of different doses of shrimp shell powder (0% SSPd, 0.25% SSPd and 0.5% SSPd) on grain yield oven dry weight (g pot^{-1}) of BRRI dhan84

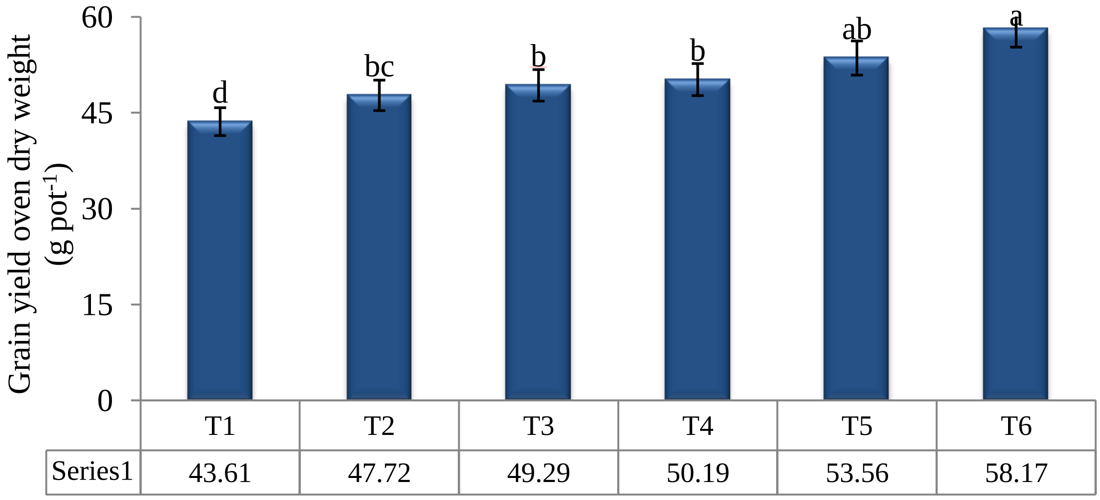


Fig.8.3: Effect of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the grain yield oven dry weight (g pot^{-1}) of BRRI dhan84. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1 = 0 µM SA + 0 % SSPd T_2 = 0 µM SA + 0.25 % SSPd T_3 = 0 µM SA + 0.5% SSPd
T_4 = 50µM SA + 0 % SSPd T_5 = 50µM SA + 0.25 % SSPd T_6 = 50µM SA + 0.5 % SSPd

Table-5: Effect of organic growth promoting substance (Shrimp Shell Powder) on grain yield sundry weight (g pot^{-1}) and grain yield oven dry weight (g pot^{-1}) of BRRI dhan84

Treatment	Grain yield Sundry weight (g pot^{-1})	Grain yield Oven dry weight (g pot^{-1})
T_1	49.59 d	43.61 d
T_2	54.12 bc	47.72 bc
T_3	56.01 b	49.29 b
T_4	57.02 b	50.19 b
T_5	60.82 ab	53.56 ab
T_6	66.35 a	58.17 a
LSD(0.05%)	6.3994	5.678
CV %	20.51	20.68
Critical Value for Comparison	6.3994	5.678

Means in a column followed by same letters are not significantly different at 5% level of significance by LSD.

4.9 Straw yield($gpot^{-1}$)

Figure-9.3, Shows the effects of different treatments on straw yield. Straw yield ($gpot^{-1}$) was significantly influenced by the shrimp shell powder treatment. Straw yield was increased due to the shrimp shell powder treatment compare to the control treatment. The highest straw yield (70.25 $gpot^{-1}$) was obtained in the T_6 (50 µM Salicylic acid + 0.5 % Shrimp shell powder) treatment which was significantly greater than that obtained in the (51.12 $gpot^{-1}$) T_1 control (0 µM Salicylic acid + 0 % Shrimp shell powder) and T_5 treatment (50 µM Salicylic acid + 0.25 Shrimp shell powder) was (63.83 $gpot^{-1}$) and T_3 (0 µM Salicylic acid + 0.5 % Shrimp shell powder) was (60.25 $gpot^{-1}$) and T_4 (50 µM Salicylic acid + 0 % Shrimp shell powder) was (59.56 $gpot^{-1}$) and T_2 (0 µM Salicylic acid + 0.25 % Shrimp shell powder) was (57.12 $gpot^{-1}$) and statistically identical to T_6 (50 µM Salicylic acid + 0.5 % Shrimp shell powder) treatment. Otherwise, The lowest straw yield (51.12 $gpot^{-1}$) was obtained in the T_1 treatment (0 µM Salicylic acid + 0 % Shrimp shell powder) control. In terms of straw yield ($gpot^{-1}$) the treatments may be arranged as T_6>T_5>T_3>T_4>T_2>T_1. It was observed that, as the rate of shrimp shell powder application in soil increases straw yield ($gpot^{-1}$) also increases.

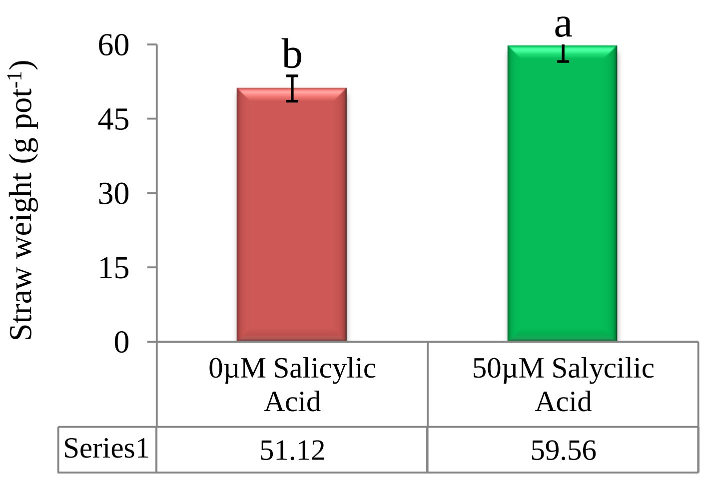


Fig-9.1: Effect of seed priming with salicylic acid on straw weight ($gpot^{-1}$) of BRRI dhan84

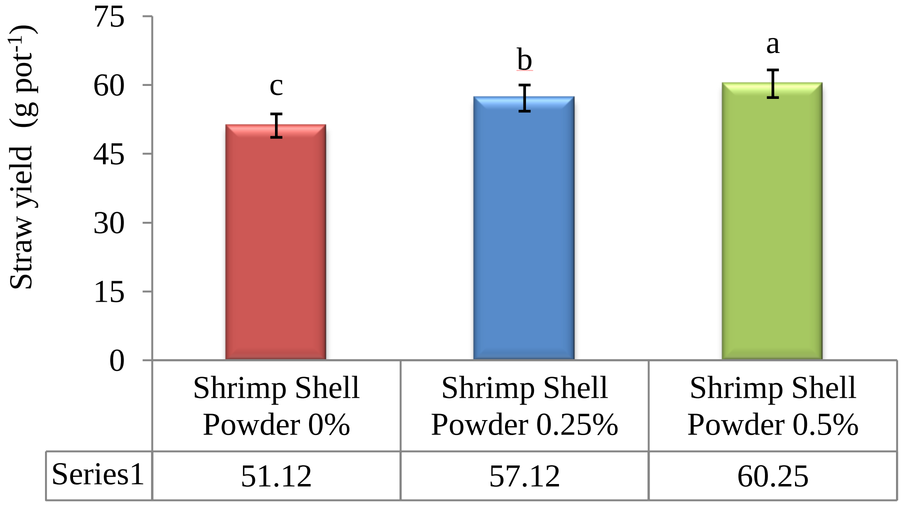


Fig-9.2: Effect of different doses of shrimp shell powder (0% SSPd, 0.25% SSPd and 0.5% SSPd) on straw yield ($gpot^{-1}$) of BRRI dhan84

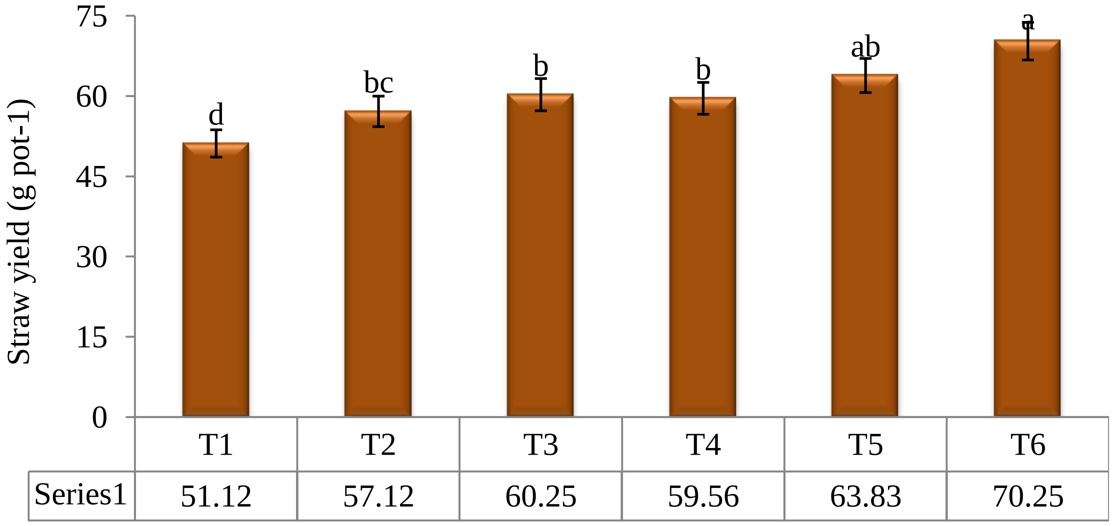


Fig.9.3: Effect of seed priming with salicylic acid and use of shrimp shell powder in seedbed on the straw yield ($gpot^{-1}$) of BRRI dhan84. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1 = 0 µM SA + 0 % SSPd T_2 = 0 µM SA + 0.25 % SSPd T_3 = 0 µM SA + 0.5% SSPd
T_4 = 50µM SA + 0 % SSPd T_5 = 50µM SA + 0.25 % SSPd T_6 = 50µM SA + 0.5 % SSPd

4.10 Nutrient content in post transplanted seedbed soil

4.10.1 Available phosphorus

A significant difference in available phosphorus content of post transplanted seedbed soil was observed at different levels of Shrimp shell powder (Table-06). The maximum available phosphorus (39.34ppm) in the post transplanted seedbed soil was recorded in T_6 treatment and the minimum available phosphorus (17.69 ppm) was noted in T_1 treatment (control). (Variable-12)

Table-06: Effect of different doses of shrimp shell powder on the available Phosphorus (P) content in post transplanted seedbed soil of BRRI dhan84

Treatment	(P) Phosphorus (ppm)
T_1	17.69 e
T_2	34.02 c
T_3	29.88 d
T_4	20.69 e
T_5	35.17 b
T_6	39.34 a
LSD(0.05%)	0.40
CV %	0.75
Critical Value for Comparison	0.40

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

4.10.2 Available Sulphur

A significant difference in available sulphur content of post transplanted seedbed soil was observed at different levels of organic material (shrimp shell powder) (Table-07). The highest available sulphur (30.36ppm) in the post transplanted seedbed soil was recorded in T_6 treatment and the lowest available sulphur (17.22 ppm) was noted in T_1 treatment (control) (Variable 11).

Table-07: Effect of different doses of shrimp shell powder on the available Sulphur(S) content in post transplanted seedbed soil of BRRI dhan84

Treatment	(S) Sulphur (ppm)
T_1	17.22 b
T_2	19.86 b
T_3	18.09 b
T_4	23.42 ab
T_5	23.27 ab
T_6	30.36 a
LSD(0.05%)	9.43
CV %	23.51
Critical Value for Comparison	9.43

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

4.11. Organic carbon content in the post transplanted seedbed soil

The organic carbon content in the post transplanted seedbed soil was affected by different treatments of organic material (shrimp shell powder) and organic carbon ranged from 0.64% to 0.78% (Table-08). It was found that Organic carbon content of soil was statistically significant. Maximum organic carbon content (0.78%) was found in T_6 treatment (50 μM Salicylic Acid + 0.5 % shrimp shell powder). However, the T_6 treatment was significantly greater than from the T_3 (0 μM Salicylic Acid + 0.5 % shrimp shell powder), T_5 (50 μM Salicylic Acid + 0.25 % shrimp shell powder), T_2 (0 μM Salicylic Acid + 0.25 % shrimp shell powder), T_4 (50 μM Salicylic Acid + 0 % shrimp shell powder) and T_1 (0 μM Salicylic Acid + 0 % shrimp shell powder) control treatment. However, minimum organic carbon content (0.64%) was found in T_1 treatment control. According to the organic carbon content of soil the treatments may be arranged as $T_6>T_3>T_5>T_2>T_4>T_1$. From this study it was observed that, as the rate of shrimp shell powder application in soil increases the organic carbon content of soil also increases. The organic carbon content was increased in a dose dependent manner; it might be due to the use of Chitosan (shrimp shell powder) containing higher level of organic carbon level. This result suggests that Chitosan (shrimp shell powder) application might be increase the level of organic matter in soils and would be helpful to improve the sustainable soil health.

4.12. Organic matter content in the post transplanted seedbed soil

Organic matter content in the post transplanted seedbed soil showed significant differences among treatments with different shrimp shell powder doses. Organic matter content ranged from 1.1% to 1.34% (table-08). Maximum organic matter content (1.34%) was found in T_6 treatment (50 μM Salicylic Acid + 0.5 % shrimp shell powder). which was significantly greater than from the T_3 (0 μM Salicylic Acid + 0.5 % shrimp shell powder), T_5 (50 μM Salicylic Acid + 0.25 % shrimp shell powder), T_2 (0 μM Salicylic Acid + 0.25 % shrimp shell powder), T_4 (50 μM Salicylic Acid + 0 % shrimp shell powder) and T_1 (0 μM Salicylic Acid + 0 % shrimp shell powder) control treatment. However, minimum organic matter content (1.1%) was found in T_1 treatment control. According to the organic matter content of soil the treatments may be arranged as $T_6>T_3>T_5>T_2>T_4>T_1$. From this study it was observed that, as the rate of shrimp shell powder application in soil increases the organic matter content of soil also increases. The organic matter content was increased in a dose dependent manner, it might be due to the use of Chitosan (shrimp shell powder) containing high amount of organic matter level. Increasing organic matter content for the sustainable agriculture is a big challenge to the Bangladesh soils; however, the Chitosan (shrimp shell powder) application could play a crucial role to increase the organic matter content in soils.

Table-08. Effects of different doses of organic material (Shrimp shell powder) on soil organic status of post transplanted seedbed soil of BRRI dhan84

Treatment	Organic Carbon %	Organic Matter %
T_1	0.64 f	1.1 f
T_2	0.72 d	1.24 d
T_3	0.76 b	1.31 b
T_4	0.65 e	1.12 e
T_5	0.74 c	1.27 c
T_6	0.78 a	1.34 a
LSD (0.05%)	0.008576	0.0172
CV %	0.66	0.77
Critical Value for Comparison	0.008576	0.0172

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

4.13. pH status of the post transplanted seedbed soil

The pH status of the post transplanted seedbed soil was affected by the different treatments of organic material (shrimp shell powder) and pH ranged from 6.3 to 6.4 (Table-09) (variable-13). It was found that pH status of soil was statistically no significant. The highest pH value (6.4) was recorded in T_6 (50 µM Salicylic Acid + 0.5 % shrimp shell powder) treatment. However, the T_6 treatment was no significantly greater than from the T_4 (50 µM Salicylic Acid + 0 % shrimp shell powder), T_1 treatment (0 µM Salicylic Acid + 0 % shrimp shell powder) control. The lowest pH value (6.3) was recorded in T_1 and T_4 treatment. From this study it was observed that, as the rate of shrimp shell powder application in soil increases the pH status of soil also increases.

Table-09: Effects of different doses of organic material (shrimp shell powder) on soil pH status of post transplanted seedbed soil of BRRI dhan84

Treatment	Soil pH
T_1	6.3
T_2	6.4
T_3	6.4
T_4	6.3
T_5	6.4
T_6	6.4
LSD (0.05%)	0.0429
CV %	0.37
Critical Value for Comparison	0.0429

Values in a column with different letters are significantly similar at $p \leq 0.05$ applying LSD.

CHAPTER 5

SUMMARY & CONCLUSION

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SUMMARY AND CONCLUSION

The pot experiment was conducted at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from December, 2020 to May 2021 to study on the effect of SSPd (Shrimp Shell Powder) on growth and yield of BRRI dhan84 in *Boro* season under the Modhupur Tract (AEZ-28). The experiment was comprised of six treatments. T_1= 0 μM Salicylic Acid + 0% Shrimp Shell Powder, T_2 = 0 μM Salicylic Acid + 0.25% Shrimp Shell Powder, T_3 = 0 μM Salicylic Acid + 0.5% Shrimp Shell Powder, T_4 = 50 μM Salicylic Acid + 0% Shrimp Shell Powder, T_5 = 50 μM Salicylic Acid + 0.25 % Shrimp Shell Powder, T_6 = 50 μM Salicylic Acid + 0.5 % Shrimp Shell Powder. The experiment was laid out in CRD design with twenty four replications. The data on crop growth and yield characters (germination percentage, seedling height, fresh weight, oven dry weight, seedling strength, number of effective tiller $hill^{-1}$, total number of tiller, number of total grain yield pot^{-1} and straw yield pot^{-1} were recorded in the field and analyzed using the software Statistix10. The mean differences among the treatments were compared by least significant difference test at 5% level of significance. Shrimp Shell Powder treatment showed that, the maximum seedling height (24.65cm) was observed in T_6 treatment and followed by T_5 (21.92cm), T_4 (21.04cm), T_2(20.55cm), T_3 (19.84cm) and whereas minimum seedling height (19.52cm) was observed in T_1 (control) treatment (Fig-4.3). The maximum seedling fresh weight (593.29 mg) was observed in T_6 treatment (Fig-2.3). Whereas minimum seedling fresh weight (239.67mg) was observed in T_1 (control). The maximum seedling oven dry weight (396.14mg) was observed in T_6 treatment (Fig-3.3). Whereas minimum productions of seedling oven dry weight (144.84 mg) was observed in T_1 (control) treatment. The maximum seedling strength (18.08mg cm^{-1}) was observed in T_6 treatment (Fig-5.3). Whereas minimum seedling strength (7.42mg cm^{-1}) was observed in T_1 (control) treatment. The maximum effective tillers $hill^{-1}$ (11.56) was obtained in T_6 (50 μM Salicylic acid + 0.5 % Shrimp shell powder) treatment, whereas the minimum effective tillers $hill^{-1}$ (7.83) was obtained in T_1 = (0 μM Salicylic acid + 0% Shrimp shell powder) treatment. The highest grain yield sundry weight (66.35 g pot^{-1}) and maximum grain yield oven dry weight (58.17 g pot^{-1}) were obtained in the T_6 (50 μM Salicylic acid + 0.5 % Shrimp shell powder) treatment which was significantly greater than that obtained in the T_1 control (0 μM Salicylic acid + 0 % Shrimp shell powder) and T_5 treatment (50 μM Salicylic acid + 0.25% Shrimp shell powder) and T_4 (50 μM Salicylic acid + 0 % Shrimp shell powder) and T_3 (0 μM Salicylic acid + 0.5 % Shrimp shell powder) and T_2 (0 μM Salicylic acid + 0.25 % Shrimp shell powder) and statistically identical to T_6 (50 μM Salicylic acid + 0.5 % Shrimp shell powder) treatment. Otherwise, The lowest grain yield sundry weight (49.59 $g\,pot^{-1}$) and lowest grain yield oven dry weight (43.61 $g\,pot^{-1}$) were obtained in the T_1 (0 μM Salicylic acid + 0 % Shrimp shell powder) control treatment. In terms of grain yield the treatments may be arranged as T_6>T_5>T_4 >T_3>T_2 $> T_1$. The highest straw yield (70.25$g\,pot^{-1}$) was obtained in the T_6 (50 μM Salicylic acid + 0.5 % Shrimp shell powder) treatment which was significantly greater than that obtained in the T_1 control (0 μM Salicylic acid + 0 % Shrimp shell powder) and T_5 treatment (50 μM Salicylic acid + 0.25 % Shrimp shell powder) and T_3 (0 μM Salicylic acid + 0.5 % Shrimp shell powder)and T_4 (50 μM Salicylic acid + 0 % Shrimp shell powder) and T_2 (0 μM Salicylic acid + 0.25% Shrimp shell powder) and statistically identical to T_6 (50 μM Salicylic acid + 0.5% Shrimp shell powder) treatment. Otherwise, the lowest straw yield (51.12$g\,pot^{-1}$) was obtained in the T_1 (0 μM Salicylic acid + 0 % Shrimp shell powder) control treatment. The present study was conducted to improve our understanding of rice responses to modified Shrimp Shell Powder application. Our results indicated beneficial effects of modified Shrimp Shell Powder application. Shrimp Shell Powder application might be increased the amount of photosynthesis, thereby increasing the number of filled grains panicle-1, hence increased spikelet fertility. The overall results of the present study demonstrated that yield maximization is induced by the application of Shrimp Shell Powder both in the seedbed applied method and field applied method. Among the application methods seedbed application could be suggested for the rice growers. However, before making conclusion concerning the appropriate dose of Shrimp Shell Powder, further investigation is needed in different Agro Ecological Zones (AEZs) of Bangladesh. Varietal trial also needed for the country-wide recommendation of using modified Shrimp Shell Powder in rice cultivation.

CHAPTER 6

REFERENCES

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CHAPTER 7

APPENDICES

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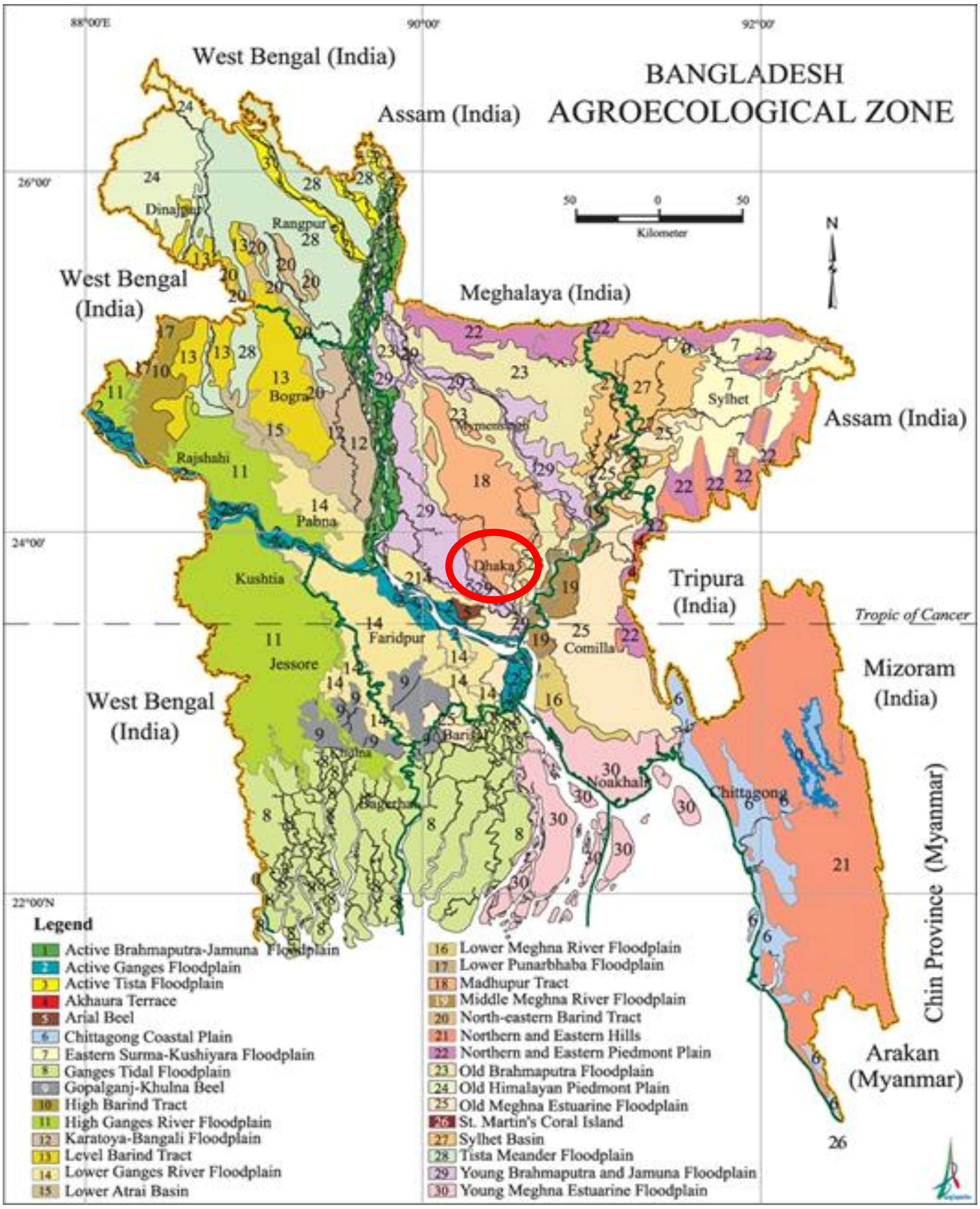
APPENDICES

Appendix III. Map showing the experimental location under study



Map showing the experimental location under study

Appendix-IV. Monthly meteorological information during the period from December, 2020 to May 2021

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2020	December	29.6	19.8	53	00
2021	January	28.8	19.1	47	00
	February	25.5	13.1	41	00
	March	25.9	14	34	7.7
	April	31.7	20.2	60	73
	May	32.7	23.8	74	168

(Source : Metrological Centre, Agargaon, Dhaka (Climate Division)

APPENDIX V : LIST OF PLATE

Plate 2: Experimental site

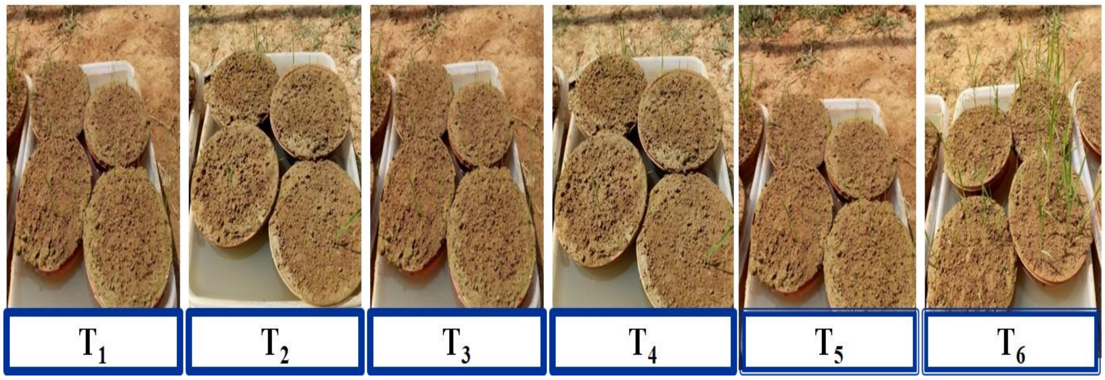


Plate 3: Seed germination

Plate 4: Seed pot preparation and seed sowing in seed pot

Plate 5: Main pot preparation for seedling transplant

Plate 6 : Transplanting seedling

Plate 7: Tiller Initiation

Plate 8: Vegetative stage

Plate 9: Flower blooming and Panicle initiation

Plate 10: Ripening Stage (Ripening grain)

Plate 11: Oven dry seedling weight

Plate 12: Fresh Seedling

Plate 13: Harvesting stage

Plate 14: Weight of Soil Sample

Plate 15: Shaking for determination of Phosphorus (P)

Plate 16: Determination of pH

Plate 17: Filtering for determination of Sulphur (S)

Plate 18: Filtering for determination of Phosphorus (P)

Plate 19: Determination of organic carbon (OC%)

Appendix VI: Analysis of variance of different variable

⌗ Variable-1.1: Effect of Seed priming with SA on seedling fresh weight

Statistix 10.0 9/24/2023, 11:57:13 AM

Randomized Complete Block AOV Table for fresh weight

Source	DF	SS	MS	F	P
repl	2	4.00003	2.00002		
treat	1	12150	12150	2.43E+08	0
Error	2	1.00E-04	5.00E-05		
Total	5	12154			
Grand Mean	284.67				
CV	0				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	1.00E-04	1.00E-04	120000	0.0018
Remainder	1	8.33E-10	8.33E-10		
Relative Efficiency, RCB		13440.62			

Means of fresh wt for treat

treat	Mean
1	239.67
4	329.67
Observations per Mean	3
Standard Error of a Mean	4.08E-03
Std Error (Diff of 2 Means)	5.77E-03

Statistix 10.0 9/24/2023, 11:57:47 AM

LSD All-Pairwise Comparisons Test of seeling fresh wt for treat

treat	Mean	Homogeneous Groups
4	329.67	A
1	239.67	B

Alpha	0.05	Standard Error for Comparison	5.77E-03
Critical T Value	4.303	Critical Value for Comparison	0.0248

All 2 means are significantly different from one another.

⌗ Variable 1.2: Effect of different doses SSPd on seedling fresh weight

Statistix 10.0 9/24/2023, 11:55:39 AM

Randomized Complete Block AOV Table for frswt

Source	DF	SS	MS	F	P
repl	2	5.37447	2.68723		

treat	2	90755.9	45377.9	5768381	0
Error	4	0.03147	7.87E-03		
Total	8	90761.3			
Grand Mean	379.46				
CV	0.02				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.00058	0.00058	0.06	0.8272
Remainder	3	0.03088	0.01029		
Relative Efficiency, RCB	79.12				

Means of seedling fresh wt for treat

treat	Mean
1	239.38
2	429.31
3	469.7
Observations per Mean	3
Standard Error of a Mean	0.0512
Std Error (Diff of 2 Means)	0.0724

LSD All-Pairwise Comparisons Test of frswt for treat

treat	Mean	Homogeneous Groups
3	469.7	A
2	429.31	B
1	239.38	C

Alpha	0.05	Standard Error for Comparison	0.0724
Critical T Value	2.776	Critical Value for Comparison	0.2011

All 3 means are significantly different from one another.

⌗ Variable-1.3: Effect on seed priming with SA and use of SSPd in seedbed on seedling fresh weight

Randomized Complete Block AOV Table for Fresh weight

Source	DF	SS	MS	F	P
rep	2	8	3.9		
treat	5	253528	50705.7	8324.89	0.0000
Error	10	61	6.1		
Total	17	253597			
Grand Mean	432.00				
CV	0.57				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	19.2512	19.2512	4.16	0.0718
Remainder	9	41.6573	4.6286		

Relative Efficiency, RCB	0.94

Means of Fwt for treat

treat	Mean
1	239.67
2	429.47
3	469.97
4	329.67
5	529.91
6	593.29

Observations per Mean	3
Standard Error of a Mean	1.4249
Std Error (Diff of 2 Means)	2.0151

LSD All-Pairwise Comparisons Test of Fresh weight for treat

treat	Mean	Homogeneous Groups
1	239.67	F
2	429.47	D
3	469.97	C
4	329.67	E
5	529.91	B
6	593.29	A

Alpha	0.05	Standard Error for Comparison	2.0151
Critical T Value	2.228	Critical Value for Comparison	4.4899

All 6 means are significantly different from one another.

⌗ Variable-2.1: Effect of Seed priming with Salicylic acid on seedling oven dry weight

Statistix 10.0 9/24/2023, 11:57:13 AM

Randomized Complete Block AOV Table for oven dry wt

Source	DF	SS	MS	F	P
repl	2	4.97	2.48		
treat	1	1490.58	1490.58	15854.43	0.0001
Error	2	0.19	0.09		
Total	5	1495.74			
Grand Mean	160.53				
CV	0.19				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.12985	0.12985	2.23	0.3755
Remainder	1	0.05818	0.05818		

Relative Efficiency, RCB 9.38

Means of oven dry wt for treat

treat	Mean
1	144.77

4	176.29	
Observations per Mean		3
Standard Error of a Mean		0.177
Std Error (Diff of 2 Means)		0.2504

LSD All-Pairwise Comparisons Test of oven dry wt for treat

treat	Mean	Homogeneous Groups
4	176.29	A
1	144.77	B

Alpha	0.05	Standard Error for Comparison	0.2504
Critical T Value	4.303	Critical Value for Comparison	1.0772

All 2 means are significantly different from one another.

⌗ Variable-2.2: Effect of different doses Shrimp shell powder on seedling oven dry weight

Statistix 10.0 9/24/2023, 11:55:39 AM

Randomized Complete Block AOV Table for oven dry wt

Source	DF	SS	MS	F	P
repl	2	3.6	1.8		
treat	2	47143.6	23571.8	278242.7	0
Error	4	0.3	0.1		
Total	8	47147.6			

Grand Mean	246.86
CV	0.12

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.16441	0.16441	2.83	0.1913
Remainder	3	0.17446	0.05815		

Relative Efficiency, RCB 5.61

Means of oven dry wt for treat

treat	Mean
1	144.65
2	293.32
3	302.61
Observations per Mean	3
Standard Error of a Mean	0.168
Std Error (Diff of 2 Means)	0.2377

LSD All-Pairwise Comparisons Test of oven dry wt for treat

treat	Mean	Homogeneous Groups
3	302.61	A
2	293.32	B
1	144.65	C

Alpha	0.05	Standard Error for Comparison	0.2377
Critical T Value	2.776	Critical Value for Comparison	0.6598

All 3 means are significantly different from one another.

⌗ Variable-2.3: Effect on seed priming with SA and use of SSPd in seedbed on seedling oven dry weight

Randomized Complete Block AOV Table for Oven dry weight

Source	DF	SS	MS	F	P
rep	2	1	0.6		
treat	5	153274	30654.7	64767.35	0.0000
Error	10	5	0.5		
Total	17	153280			

Grand Mean 279.82

CV 0.25

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	1.26544	1.26544	3.28	0.1034
Remainder	9	3.46762	0.38529		

Relative Efficiency, RCB 1.00

Means of Oven dry weight for treat

treat	Mean
1	144.84
2	293.05
3	302.39
4	175.06
5	367.46
6	396.14

Observations per Mean	3
Standard Error of a Mean	0.3972
Std Error (Diff of 2 Means)	0.5617

LSD All-Pairwise Comparisons Test of Oven Dry Weight for treat

treat	Mean	Homogeneous Groups
1	144.84	F
2	293.05	D
3	302.39	C
4	175.06	E
5	367.46	B
6	396.14	A

Alpha	0.05	Standard Error for Comparison	0.5617

Critical T Value 2.228 Critical Value for Comparison 1.2516
All 6 means are significantly different from one another.

⌗ Variable-3.1: Effect of Seed priming with Salicylic acid on seedling height

Statistix 10.0 9/24/2023, 11:57:13 AM

Randomized Complete Block AOV Table for seedling height

Source	DF	SS	MS	F	P
repl	2	3.83223	1.91612		
treat	1	4.89607	4.89607	108.76	0.0091
Error	2	0.09003	0.04502		
Total	5	8.81833			
Grand Mean	20.227				
CV	1.05				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.02003	0.02003	0.29	0.6873
Remainder	1	0.07	0.07		
Relative Efficiency, RCB	14.81				

Means of seedling height for treat

treat	Mean
1	19.323
4	21.13

Observations per Mean	3
Standard Error of a Mean	0.1225
Std Error (Diff of 2 Means)	0.1732

⌗ Variable-3.2: Effect of different doses Shrimp shell powder on seedling height

Statistix 10.0 9/24/2023, 11:55:39 AM

Randomized Complete Block AOV Table for seedling height

Source	DF	SS	MS	F	P
repl	2	2.04776	1.02388		
treat	2	2.21216	1.10608	43.58	0.0019
Error	4	0.10151	0.02538		
Total	8	4.36142			
Grand Mean	20.644				
CV	0.77				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.02144	0.02144	0.8	0.4361

Remainder	3	0.08007	0.02669
Relative Efficiency, RCB	9.95		

Means of seedling height for treat

treat	Mean
1	20.09
2	21.293
3	20.55
Observations per Mean	3
Standard Error of a Mean	0.092
Std Error (Diff of 2 Means)	0.1301

LSD All-Pair wise Comparisons Test of seedling height for treat

treat	Mean	Homogeneous Groups
2	21.293	A
3	20.55	B
1	20.09	C

Alpha	0.05	Standard Error for Comparison	0.1301
Critical T Value	2.776	Critical Value for Comparison	0.3611

All 3 means are significantly different from one another.

⌗ Variable-3.3: Effect on seed priming with SA and use of SSPd in seedbed on seedling height

Randomized Complete Block AOV Table for Seedling height

Source	DF	SS	MS	F	P
rep	2	0.2646	0.1323		
treat	5	52.5472	10.5094	87.05	0.0000
Error	10	1.2073	0.1207		
Total	17	54.0190			
Grand Mean	21.254				
CV	1.63				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.02142	0.02142	0.16	0.6962
Remainder	9	1.18587	0.13176		
Relative Efficiency, RCB	0.99				

Means of Seedling height for treat

treat	Mean
1	19.523
2	20.553
3	19.837
4	21.043
5	21.920
6	24.650
Observations per Mean	3

Standard Error of a Mean	0.2006
Std Error (Diff of 2 Means)	0.2837

LSD All-Pairwise Comparisons Test of Seedling height for treat

treat	Mean	Homogeneous Groups
1	19.523	D
2	20.553	C
3	19.837	D
4	21.043	C
5	21.920	A
6	24.650	B

Alpha	0.05	Standard Error for Comparison	0.2837
Critical T Value	2.228	Critical Value for Comparison	0.6321

There are 4 groups (A, B, etc.) in which the means
are not significantly different from one another.

⌗ Variable-4.1: Effect of Seed priming with Salicylic acid on seedling strength

Statistix 10.0 9/24/2023, 11:57:13 AM

Randomized Complete Block AOV Table for seedling strength

Source	DF	SS	MS	F	P
repl	2	0.5227	0.26135		
treat	1	1.65375	1.65375	189	0.0052
Error	2	0.0175	0.00875		
Total	5	2.19395			
Grand Mean	7.985				
CV	1.17				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.00014	0.00014	0.01	0.9433
Remainder	1	0.01736	0.01736		

Relative Efficiency, RCB 10.54

Means of seedling strength for treat

treat	Mean
1	7.46
4	8.51
Observations per Mean	3
Standard Error of a Mean	0.054
Std Error (Diff of 2 Means)	0.0764

LSD All-Pairwise Comparisons Test of seedling strength for treat

treat	Mean	Homogeneous Groups	
4	8.51	A	
1	7.46	B	
Alpha	0.05	Standard Error for Comparison	0.0764
Critical T Value	4.303	Critical Value for Comparison	0.3286

All 2 means are significantly different from one another.

⌗ Variable-4.2: Effect of different doses Shrimp shell powder on seedling strength

Statistix 10.0 9/24/2023, 11:55:39 AM

Randomized Complete Block AOV Table for seedling strength

Source	DF	SS	MS	F	P
repl	2	1.664	0.8321		
treat	2	111.17	55.5852	13340.46	0
Error	4	0.017	0.0042		
Total	8	112.851			
Grand Mean	12.833				
CV	0.5				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.00141	1.41E-03	0.28	0.6344
Remainder	3	0.01525	5.08E-03		

Relative Efficiency, RCB 46.54

Means of seedling strength for treat

treat	Mean
1	7.89
2	14.857
3	15.753
Observations per Mean	3

Standard Error of a Mean 0.0373

Std Error (Diff of 2 Means) 0.0527

LSD All-Pairwise Comparisons Test of seedling strength for treat

treat	Mean	Homogeneous Groups
3	15.753	A
2	14.857	B
1	7.89	C

Alpha	0.05	Standard Error for Comparison	0.0527
Critical T Value	2.776	Critical Value for Comparison	0.1463

All 3 means are significantly different from one another.

⌗ Variable-4.3: Effect on seed priming with SA and use of SSPd in seedbed on seedling strength

Randomized Complete Block AOV Table for Seedling Strength

Source	DF	SS	MS	F	P
rep	2	0.079	0.0395		
treat	5	267.429	53.4858	773.95	0.0000
Error	10	0.691	0.0691		
Total	17	268.199			
Grand Mean	13.038				

CV 2.02

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.00043	0.00043	0.01	0.9422
Remainder	9	0.69065	0.07674		

Relative Efficiency, RCB 0.93

Means of Seedling Strength for treat

treat	Mean
1	7.420
2	14.259
3	15.242
4	8.317
5	14.911
6	18.081

Observations per Mean 3
Standard Error of a Mean 0.1518
Std Error (Diff of 2 Means) 0.2146

LSD All-Pairwise Comparisons Test of Seedling Strength for treat

treat	Mean	Homogeneous Groups
1	7.42	E
2	14.259	C
3	15.242	B
4	8.317	D
5	14.911	B
6	18.081	A

Alpha	0.05	Standard Error for Comparison	0.2146
Critical T Value	2.228	Critical Value for Comparison	0.4783

There are 5 groups (A, B, etc.) in which the means
are not significantly different from one another.

⌗ Variable-5.1: Effect of Seed priming with Salicylic acid on Seedling Effective tiller

Statistix 10.0 9/24/2023, 11:57:13 AM

Randomized Complete Block AOV Table for effective tiller

Source	DF	SS	MS	F	P
repl	2	0.1729	0.08645		
treat	1	5.70375	5.70375	884.3	0.0011
Error	2	0.0129	0.00645		
Total	5	5.88955			
Grand Mean	8.975				
CV	0.89				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.01283	0.01283	184.87	0.0467
Remainder	1	0.00007	0.00007		

Relative Efficiency, RCB 5.01

Means of effective tiller l for treat

treat	Mean
1	8
4	9.95

Observations per Mean 3
Standard Error of a Mean 0.0464
Std Error (Diff of 2 Means) 0.0656
LSD All-Pairwise Comparisons Test of effective tiller for treat

treat	Mean	Homogeneous Groups
4	9.95	A
1	8	B

Alpha 0.05 Standard Error for Comparison 0.0656
Critical T Value 4.303 Critical Value for Comparison 0.2821
All 2 means are significantly different from one another.

⌗ Variable-5.2: Effect of different doses Shrimp shell powder on Seedling effective tiller

Statistix 10.0 9/24/2023, 11:55:39 AM

Randomized Complete Block AOV Table for effective tiller

Source	DF	SS	MS	F	P
repl	2	0.5973	0.29863		
treat	2	10.1894	5.0947	90.6	0.0005
Error	4	0.2249	0.05623		
Total	8	11.0116			

Grand Mean 9.5633
CV 2.48

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.08708	0.08708	1.9	0.2624
Remainder	3	0.13785	0.04595		

Relative Efficiency, RCB 1.91

Means of efftill for treat

treat	Mean
1	8.167
2	9.777
3	10.747

Observations per Mean 3
Standard Error of a Mean 0.1369
Std Error (Diff of 2 Means) 0.1936

LSD All-Pairwise Comparisons Test of effective tiller for treat

treat	Mean	Homogeneous Groups
3	10.747	A
2	9.777	B
1	8.167	C

Alpha	0.05	Standard Error for Comparison	0.1936
Critical T Value	2.776	Critical Value for Comparison	0.5376

All 3 means are significantly different from one another.

⌗ Variable-6: Effect on seed priming with SA and use of SSPd in seedbed on Seedling germination (%)

Statistix 10.0 9/5/2023, 11:06:00 AM

Randomized Complete Block AOV Table for germination percentage

Source	DF	SS	MS	F	P
rep	2	11.444	5.722		
treat	5	531.611	106.322	233.39	0
Error	10	4.556	0.456		
Total	17	547.611			
Grand Mean	69.722				
CV	0.97				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.06477	0.06477	0.13	0.7269
Remainder	9	4.49078	0.49898		
Relative Efficiency, RCB	2.3				

Means of germ for treat

treat	Mean
1	62
2	73
3	68.67
4	67.02
5	75
6	78.89
Observations per Mean	3
Standard Error of a Mean	0.3897
Std Error (Diff of 2 Means)	0.5511

Statistix 10.0 9/5/2023, 11:07:09 AM

LSD All-Pairwise Comparisons Test of germination for treat

treat	Mean	Homogeneous Groups
1	62	F
2	73	C
3	68.67	D

4	67.02	E
5	75	B
6	78.89	A

Alpha 0.05 Standard Error for Comparison 0.5511
Critical T Value 2.228 Critical Value for Comparison 1.2279
All 6 means are significantly different from one another.

⌗ Variable-7.1: Effect of Seed priming with Salicylic acid on Grain yield Sundry weight (g pot^{-1})

Statistix 10.0 9/24/2023, 11:57:13 AM

Randomized Complete Block AOV Table for grain yield sundry wt

Source	DF	SS	MS	F	P
repl	2	3.6532	1.8266		
treat	1	89.9388	89.9388	2439.57	0.0004
Error	2	0.0737	0.0369		
Total	5	93.6657			
Grand Mean	53.185				
CV	0.36				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.00038	0.00038	0.01	0.9541
Remainder	1	0.07335	0.07335		

Relative Efficiency, RCB 17.15

Means of grain yield sundry wt for treat

treat	Mean
1	49.313
4	57.057

Observations per Mean 3
Standard Error of a Mean 0.1109
Std Error (Diff of 2 Means) 0.1568

LSD All-Pairwise Comparisons Test of grain yield sundry wt for treat

treat	Mean	Homogeneous Groups
4	57.057	A
1	49.313	B

Alpha 0.05 Standard Error for Comparison 0.1568
Critical T Value 4.303 Critical Value for Comparison 0.6745
All 2 means are significantly different from one another.

⌗ Variable-6.2: Effect of different doses Shrimp shell powder on Grain yield Sundry weight (g pot^{-1})

Statistix 10.0 9/24/2023, 11:55:39 AM

Randomized Complete Block AOV Table for grain yield sundry wt

Source	DF	SS	MS	F	P
repl	2	4.4573	2.2286		
treat	2	77.4014	38.7007	434.19	0
Error	4	0.3565	0.0891		
Total	8	82.2152			
Grand Mean	53.263				
CV	0.56				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.07404	0.07404	0.79	0.4405
Remainder	3	0.28249	0.09416		
Relative Efficiency, RCB		6.43			

Means of grain yield sundry wt for treat

treat	Mean
1	49.277
2	54.267
3	56.247

Observations per Mean	3
Standard Error of a Mean	0.1724
Std Error (Diff of 2 Means)	0.2438

LSD All-Pairwise Comparisons Test of grain yield sundry wt for treat

treat	Mean	Homogeneous Groups
3	56.247	A
2	54.267	B
1	49.277	C

Alpha	0.05	Standard Error for Comparison	0.2438
Critical T Value	2.776	Critical Value for Comparison	0.6768

All 3 means are significantly different from one another.

⌗ Variable-6.3: Effect on seed priming with SA and use of SSPd in seedbed on Grain yield Sundry weight (g pot^{-1})

Statistix 10.0 (30-day Trial)

Randomized Complete Block AOV Table for Grain yield sundry wt

Source	DF	SS	MS	F	P
rep	5	1232.9	246.57		
treat	5	7781	1556.2	12.39	0
Error	133	16706.3	125.61		
Total	143	25720.2			

Grand Mean	54.645
CV	20.51
Relative Efficiency, RCB	1.14

Means of Fwt for treat

treat	Mean
1	49.59
2	54.12
3	56.01
4	57.02
5	60.82
6	66.35
Observations per Mean	24
Standard Error of a Mean	2.2877
Std Error (Diff of 2 Means)	3.2354

Statistix 10.0 (30-day Trial)

LSD All-Pairwise Comparisons Test of grain yield sundry weight for treat

treat	Mean	Homogeneous Groups
1	49.59	D
2	54.12	BC
3	56.01	B
4	57.02	B
5	60.82	AB
6	66.35	A

Alpha	0.05	Standard Error for Comparison	3.2354
Critical T Value	1.978	Critical Value for Comparison	6.3994

There are 4 groups (A, B, etc.) in which the means
are not significantly different from one another.

⌗ Variable-7.1: Effect of Seed priming with Salicylic acid on Grain yield oven dry weight (g pot^{-1})

Statistix 10.0 9/24/2023, 11:57:13 AM

Randomized Complete Block AOV Table for grain yield oven dry wt

Source	DF	SS	MS	F	P
repl	2	3.019	1.5095		
treat	1	71.9681	71.9681	387.93	0.0026
Error	2	0.371	0.1855		
Total	5	75.3581			
Grand Mean	46.993				
CV	0.92				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.24977	0.24977	2.06	0.3874
Remainder	1	0.12126	0.12126		

Relative Efficiency, RCB 3.24

Means of grain yield oven dry for treat

treat	Mean
1	43.53
4	50.457

Observations per Mean 3
Standard Error of a Mean 0.2487
Std Error (Diff of 2 Means) 0.3517

LSD All-Pairwise Comparisons Test of grain yield oven dry for treat

treat	Mean	Homogeneous Groups
4	50.457	A
1	43.53	B

Alpha	0.05	Standard Error for Comparison	0.3517
Critical T Value	4.303	Critical Value for Comparison	1.5132

All 2 means are significantly different from one another.

⌗ Variable-7.2: Effect of different doses Shrimp shell powder on Grain yield oven dry weight (g pot^{-1})

Statistix 10.0 9/24/2023, 11:55:39 AM

Randomized Complete Block AOV Table for grain yield oven dry

Source	DF	SS	MS	F	P
repl	2	2.9954	1.4977		
treat	2	59.5916	29.7958	56.47	0.0012
Error	4	2.1106	0.5277		
Total	8	64.6976			

Grand Mean 47.114
CV 1.54

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.41434	0.41434	0.73	0.4549
Remainder	3	1.6963	0.56543		

Relative Efficiency, RCB 1.34

Means of grain yield oven dry for treat

treat	Mean
1	43.723
2	47.667
3	49.953

Observations per Mean 3
Standard Error of a Mean 0.4194
Std Error (Diff of 2 Means) 0.5931

LSD All-Pairwise Comparisons Test of grain yield oven dry for treat

treat	Mean	Homogeneous Groups
3	49.953	A
2	47.667	B
1	43.723	C

Alpha	0.05	Standard Error for Comparison	0.5931
Critical T Value	2.776	Critical Value for Comparison	1.6467

All 3 means are significantly different from one another.

⌗ Variable-7.3: Effect on seed priming with SA and use of SSPd in seedbed on Grain yield oven dry weight (g pot^{-1})

Statistix 10.0 (30-day Trial) 5/31/2023, 2:31:43 PM

Randomized Complete Block AOV Table for grain yield oven dry wt

Source	DF	SS	MS	F	P
rep	5	952.7	190.55		
treat	5	5906.8	1181.36	11.95	0
Error	133	13152	98.89		
Total	143	20011.5			
Grand Mean	48.088				
CV	20.68				
Relative Efficiency, RCB	1.13				

Means of grain yield oven dry wt t for treat

treat	Mean
1	43.61
2	47.72
3	49.29
4	50.19
5	53.56
6	58.17
Observations per Mean	24
Standard Error of a Mean	2.0298
Std Error (Diff of 2 Means)	2.8706

LSD All-Pairwise Comparisons Test of grain yield oven dry weight for treat

treat	Mean	Homogeneous Groups
1	43.61	D
2	47.72	BC
3	49.29	B
4	50.19	B
5	53.56	AB
6	58.17	A

Alpha 0.05 Standard Error for Comparison 2.8706
Critical T Value 1.978 Critical Value for Comparison 5.678
There are 4 groups (A, B, etc.) in which the means
are not significantly different from one another.

⌗ Variable-8.1: Effect of Seed priming with Salicylic acid on straw yield sundry weight ($g\ pot^{-1}$)

Statistix 10.0 9/24/2023, 11:57:13 AM

Randomized Complete Block AOV Table for straw yield sundry weight

Source	DF	SS	MS	F	P
repl	2	1.586	0.793		
treat	1	128.529	128.529	243.6	0.0041
Error	2	1.055	0.528		
Total	5	131.17			
Grand Mean	55.025				
CV	1.32				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.13325	0.13325	0.14	0.7687
Remainder	1	0.92198	0.92198		

Relative Efficiency, RCB 1.01

Means of straw yield sundry weight for treat

treat	Mean
1	50.397
4	59.653

Observations per Mean 3
Standard Error of a Mean 0.4194
Std Error (Diff of 2 Means) 0.5931

LSD All-Pairwise Comparisons Test of straw yield sundry weight for treat

treat	Mean	Homogeneous Groups
3	60.49	A
2	57.41	B
1	51.267	C

Alpha 0.05 Standard Error for Comparison 0.1068
Critical T Value 2.776 Critical Value for Comparison 0.2964
All 3 means are significantly different from one another.

⌗ Variable-8.2: Effect of different doses Shrimp shell powder on straw yield sundry weight (g pot^{-1})

Statistix 10.0 9/24/2023, 11:55:39 AM

Randomized Complete Block AOV Table for straw yield sundry weight

Source	DF	SS	MS	F	P
repl	2	3.74	1.8701		
treat	2	132.297	66.1484	3869.59	0
Error	4	0.068	0.0171		
Total	8	136.105			
Grand Mean	56.389				
CV	0.23				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.02256	0.02256	1.48	0.3112
Remainder	3	0.04582	0.01527		

Relative Efficiency, RCB 25.81

Means of straw yield sundry weight for treat

treat	Mean
1	51.267
2	57.41
3	60.49

Observations per Mean 3
Standard Error of a Mean 0.0755
Std Error (Diff of 2 Means) 0.1068

LSD All-Pairwise Comparisons Test of straw yield sundry weight for treat

treat	Mean	Homogeneous Groups
3	60.49	A
2	57.41	B
1	51.267	C

Alpha 0.05 Standard Error for Comparison 0.1068
Critical T Value 2.776 Critical Value for Comparison 0.2964
All 3 means are significantly different from one another.

⌗ Variable-9: Organic carbon (%)

Statistix 10.0 (30-day Trial) 5/31/2023, 2:31:43 PM

Randomized Complete Block AOV Table for Organic carbon

Source	**DF**	**SS**	**MS**	**F**	**P**
rep	2	0.00004	2.222E-05		
treat	5	0.04978	9.956E-03	448.00	0.0000
Error	10	0.00022	2.222E-05		
Total	17	0.05004			
Grand Mean	0.7144				
CV	0.66				

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	2.536E-05	2.536E-05	1.16	0.3096
Remainder	9	1.969E-04	2.187E-05		

Relative Efficiency, RCB 0.98

Means of Organic carbon for treat

treat	Mean
1	0.6400
2	0.7200
3	0.7600
4	0.6500
5	0.7367
6	0.7800

Observations per Mean 3
Standard Error of a Mean 2.722E-03
Std Error (Diff of 2 Means) 3.849E-03

LSD All-Pairwise Comparisons Test of Organic carbon for treat

treat	Mean	Homogeneous Groups
6	0.7800	A
3	0.7600	B
5	0.7367	C
2	0.7200	D
4	0.6500	E
1	0.6400	F

Alpha	0.05	Standard Error for Comparison	3.849E-03
Critical T Value	2.228	Critical Value for Comparison	8.576E-03

All 6 means are significantly different from one another.

⌗ Variable-10: Organic Matter (%)

Statistix 10.0 (30-day Trial) 5/31/2023, 2:31:43 PM

Randomized Complete Block AOV Table for Organic Matter

Source	DF	SS	MS	F	P
rep	2	0.00018	0.00009		
treat	5	0.14843	0.02969	333.96	0.0000
Error	10	0.00089	0.00009		
Total	17	0.14949			

Grand Mean 1.2306
CV 0.77

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	1.065E-04	1.065E-04	1.22	0.2971
Remainder	9	7.824E-04	8.693E-05		

Relative Efficiency, RCB 0.98

Means of Organic Matter for treat

treat	Mean
1	1.1000
2	1.2400
3	1.3100
4	1.1200
5	1.2733
6	1.3400

Observations per Mean	3
Standard Error of a Mean	5.443E-03
Std Error (Diff of 2 Means)	7.698E-03

LSD All-Pairwise Comparisons Test of Organic Matter for treat

treat	Mean	Homogeneous Groups
6	1.3400	A
3	1.3100	B
5	1.2733	C
2	1.2400	D
4	1.1200	E
1	1.1000	F

Alpha	0.05	Standard Error for Comparison	7.698E-03
Critical T Value	2.228	Critical Value for Comparison	0.0172

All 6 means are significantly different from one another.

⌗ Variable-11: Sulphur of Soil (ppm)

Statistix 10.0 4/17/2023, 2:30:52 PM

Randomized Complete Block AOV Table for Sulphur

Source	DF	SS	MS	F	P
rep	2	22.153	11.0766		
treat	5	348.517	69.7035	2.60	0.0934
Error	10	268.401	26.8401		
Total	17	639.071			

Grand Mean	22.036
CV	23.51

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	218.402	218.402	39.31	0.0001
Remainder	9	49.998	5.555		

Relative Efficiency, RCB 0.91

Means of Sulphur for treat

treat	Mean
1	17.220
2	19.860
3	18.090
4	23.423
5	30.357
6	23.267

Observations per Mean 3

Standard Error of a Mean	2.9911
Std Error (Diff of 2 Means)	4.2301

LSD All-Pairwise Comparisons Test of Sulphur for treat

treat	Mean	Homogeneous Groups
5	30.357	A
4	23.423	AB
6	23.267	AB
2	19.860	B
3	18.090	B
1	17.220	B

Alpha	0.05	Standard Error for Comparison	4.2301
Critical T Value	2.228	Critical Value for Comparison	9.4252

⌗ Variable 12: Phosphorus of Soil (ppm)

Statistix 10.0 4/17/2023, 2:34:41 PM

Randomized Complete Block AOV Table for Phosphorus

Source	DF	SS	MS	F	P
rep	2	0.06	0.030		
treat	5	1099.94	219.988	4487.82	0.0000
Error	10	0.49	0.049		
Total	17	1100.49			

Grand Mean	29.467
CV	0.75

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	0.05912	0.05912	1.23	0.2953
Remainder	9	0.43106	0.04790		

Relative Efficiency, RCB 0.93

Means of Phosphorus for treat

treat	Mean
1	20.693
2	34.023
3	29.883
4	17.690
5	39.340
6	35.173

Observations per Mean	3
Standard Error of a Mean	0.1278
Std Error (Diff of 2 Means)	0.1808

LSD All-Pairwise Comparisons Test of Phosphorus for treat

treat	Mean	Homogeneous Groups
5	39.340	A
6	35.173	B
2	34.023	C
3	29.883	D

1	20.693	E
4	17.690	F

Alpha	0.05	Standard Error for Comparison	0.1808
Critical T Value	2.228	Critical Value for Comparison	0.4028

All 6 means are significantly different from one another.

⌗ Variable 13: Soil pH

Statistix 10.0 4/17/2023, 2:37:16 PM

Randomized Complete Block AOV Table for pH

Source	DF	SS	MS	F	P
rep	2	0.00111	0.00056		
treat	5	0.06444	0.01289	23.20	0.0000
Error	10	0.00556	0.00056		
Total	17	0.07111			

Grand Mean 6.3778
CV 0.37

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source	DF	SS	MS	F	P
Nonadditivity	1	2.452E-03	2.452E-03	7.11	0.0258
Remainder	9	3.103E-03	3.448E-04		

Relative Efficiency, RCB 0.98

Means of pH for treat

treat	Mean
1	6.3000
2	6.4000
3	6.4000
4	6.3000
5	6.4000
6	6.4667

Observations per Mean	3
Standard Error of a Mean	0.0136
Std Error (Diff of 2 Means)	0.0192

Statistix 10.0 4/17/2023, 2:37:50 PM

LSD All-Pairwise Comparisons Test of pH for treat

treat	Mean	Homogeneous Groups
6	6.4667	A
2	6.4000	A
3	6.4000	A
5	6.4000	A
1	6.3000	A
4	6.3000	A

Alpha	0.05	Standard Error for Comparison	0.0192
Critical T Value	2.228	Critical Value for Comparison	0.0429