EFFECT OF DECOMPOSED SHRIMP SHELL POWDER ON THE GROWTH, YIELD AND NUTRIENT CONTENT OF INDIAN SPINACH (*Basella alba*)

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JUNE, 2022

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By

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REG. NO. : 14-05965

A Thesis

Submitted to the Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements for the degree
Of

MASTER OF SCIENCE (MS)
IN
SOIL SCIENCE
SEMESTER: JANUARY-JUNE, 2022

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*This is to certify that thesis entitled, "EFFECT OF DECOMPOSED SHRIMP SHELL POWDER ON THE GROWTH, YIELD AND NUTRIENT CONTENT OF INDIAN SPINACH (Basella alba)" 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 **ANAMIKA DAS**, **Registration no .14-05965** 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

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Dedicated To

My Beloved Parents

And Respected Teachers

Whose Prayers,

Efforts And

Wishes Are an

Inspiration

ACKNOWLEDGEMET

All praises are devoted to the Almighty, who enables the author to complete the research work and prepare this thesis for the degree of Master of Science (M.S.) in Soil Science.

The author feels proud to express her heartfelt gratitude and immense indebtedness to her respected supervisor ***Prof. Dr. Mohammad Issak****, Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh for his erudite guidance, support, encouragement and valuable suggestions throughout the study.*

Likewise, grateful appreciation is conveyed to her Co-Supervisor, ***Prof. Dr. Md. Asaduzzaman Khan****, for his cordial suggestions valuable advices and constructive criticisms to complete the thesis paper.*

The author wants to express her sincere gratitude to her respectable teacher ***Dr. Mohammad Saiful Islam Bhuiyan****, Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 for her valuable advice and providing necessary facilities to conduct the research work.*

The author would like to express her deepest respect and gratitude to all the respected teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, for there valuable lectures, advices, sympathetic co-operation and inspiration throughout the course of the study.

The author wants to extend her special thanks to Ministry of Science and Technology authority for providing the NST fellowship to run smoothly the research activities.

The author wishes to express her special thanks to her husband Mr. Nihar Sarker for his immense support and cordial help in her study and preparation of thesis paper.

Finally, the author expresses her deepest sense of gratitude to her beloved parents, brothers, sisters, other family members, relatives, well-wishers and friends for their inspiration, help and encouragement throughout the study.

Finally the author would like to appreciate the assistance rendered by the staff members of Department of Soil Science, specially Md. Haider Ali, who helped her during the period of the research work.

The Author

EFFECT OF DECOMPOSED SHRIMP SHELL POWDER ON THE GROWTH, YIELD AND NUTRIENT CONTENT OF INDIAN SPINACH (*Basella alba*)

ABSTRACT

Chitin and chitosan are naturally-occurring compounds that have potential use in agriculture. Shrimp shell powder was decomposed with cowdung and the decomposed shrimp shell powder was analyzed and found as a good source of plant nutrition and soil productivity. A field experiment was conducted at the net house of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during the period from December, 2020 to March , 2021 to study the effect of decomposed shrimp shell powder on the growth, yield and nutrient content under Indian spinach (*Basella alba*) cultivation. The experiment was designed with eight treatments using seven different levels of the decomposed shrimp shell powder and the treatments were as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Results revealed that application of the decomposed shrimp shell powder significantly improves plants growth characters viz. plant height, fresh weight, oven dry weight etc. and also improves nutrient content of post-harvest soil viz. OM & OC, total nitrogen, available phosphorous & available sulphur. Results also revealed that application decomposed SSP improves soil pH. With the increasing dose of the decomposed SSP, most of the morphological and yield attributes of Indian spinach as well as soil fertility were increased. Whereas, control plants showed the lowest value of above parameters. The maximum, yield and nutrient status of post-harvest soil were recorded in T_8. The experimental results revealed that the decomposed SSP had no negative impact on the production of Indian spinach. 3% and 4% application of the decomposed SSP in soil also gives similar yield as 5% application. The experimental results disclosed that T8 having 5% application of decomposed SSP performed well and produced maximum plant height, total fresh weight , oven dry weight of Indian spinach. The treatments T_5, T_6, T_7 had statistically similar results with the treatment T_8 in case of plant height and fresh weight. The treatment T_7 had highest individual plant weight. Results also showed that T_8 had maximum value of soil chemical characteristic such as soil organic matter content, organic carbon content, total nitrogen, available phosphorous and available sulphur content in post-harvest soil. Soil pH value was also increased by using the organic manure/material. Taken together, the results indicate that the application of the decomposed SSP in soil has a significant effect on the growth & yield and nutrient content of Indian spinach and it also improves the soil fertility. The material could play a significant role in organic vegetable production.

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LIST OF ACRONYMS

Abbreviation	Full form
AEZ	Agro-Ecological Zone
ANOVA	Analysis of variance
B	Boron
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
Ca	Calcium
CD	Cow dung
CHI/ CHT	Chitosan
cm	Centimeter
CP	Coir pith
cv.	Cultivar
$CaCl_2$	Calcium chloride
^0C	Degree Celsius
DAS	Days after sowing
DAT	Days after transplanting
et al	And others
etc	Et cetra
Fig	Figure
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
i.e.	ed est (means That is)
IU	International Unit

K	Potassium
kg	Kilogram
LSD	Least Significant Difference
m	Meter
m^2	Meter squares
MCT-P	Micro Carbon TechnologyTM
Mg	Magnesium
mm	Millimeter
N	Nitrogen
No.	Number
NS	Non-significant
%	Percentage
P	Phosphorous
pH	Negative logarithm of hydrogen ion concentration (mole/L)
ppm	Parts per million
RCBD	Randomized Complete Block Design
RDA	Recommended Daily Allowance
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources Development Institute
OM	Organic matter
OC	Organic carbon
spp.	Species (plural form)
SSC	Shrimp shell compost
SSP	Shrimp shell powder
USDA	United States Department of Agriculture
var.	Variety
viz.	Namely

CHAPTER I

INTRODUCTION

Leaf vegetables also called leafy greens, pot herbs, vegetable greens, or simply greens, are plant leaves eaten as a vegetable, sometimes accompanied by tender petioles and shoots. Leaf vegetables can be eaten as raw in a salad or by cooking. Eating a diet rich in leafy greens can offer numerous health benefits including reduced risk of obesity, heart disease, high blood pressure and mental decline. In Bangladesh Pui Shak (*Basella alba*) is a commonly cultivated leaf vegetable.

Indian spinach (*Basella alba L.*) is the most popular and nutritious leafy vegetable crop in Bangladesh. It is widely grown not only in Bangladesh but also in tropical Asia and Africa (Bose *et al*., 2008). It has a great adaptability to a wide range of soil and climate in Bangladesh, that's why it is cultivated in almost all home gardens and also in the fields. The nutritive value of the young shoots and leaves is very high. According to Bose *et al*. (2008), the plant is reported to contain Protein 1.9%, Carbohydrate 3.0%, Iron 1.4 mg/100g, Vitamin A 3250 IU100g^{-1}, and Calcium 0.15%. Indian Spinach is very low in calories and fats (100 grams of raw leaves provide just 19 calories). Moreover, it holds a good amount of minerals and antioxidants. The leaves and stem are especially rich sources of vitamin A. 100 g fresh leaves provide 8000 IU or 267% of recommended daily allowance (RDA) of Vitamin A. Vitamin-A is essential for good eyesight and required for maintaining healthy mucus membranes and skin. Consumption of natural vegetables and fruits rich in vitamin-A and flavonoids has been thought to offer protection from lung and oral cavity cancers. 100 g of fresh greens contains 102 mg vitamin-C. Vitamin-C is a powerful antioxidant, it helps the human body to develop resistance against infectious agents and scavenge harmful oxygen-free radicals. Indian Spinach also contains good amounts of many B-complex vitamins such as folate, vitamin-B6 (pyridoxine), and riboflavin. 100 g fresh leaves provide 140 µg of folates. Basella leaves are also good sources of minerals like Potassium (11% of RDA 100g^{-1}), Manganese (32% of RDA 100g^{-1}), Calcium, and Magnesium (Source: USDA National Nutrient data base). Regular consumption of Indian Spinach in the diet helps to prevent osteoporosis (weakness of bones), iron-deficiency anemia. Besides, it is believed to protect from cardiovascular diseases and colon cancers. With the increase of population, the demand of Indian Spinach (Pui shak) in our country is increasing day by day. The yield performance of Indian spinach is very poor in Bangladesh, about only 10-13 tons ha^{-1} (Hoque, 2005). So, it is urgent to increase yield by proper management and cultural practices. Plant growth regulators are one of the most important factors for increasing higher yield in leafy vegetables.

Now-a-days agricultural sector is facing the intimidating challenge to feed the huge population by applying chemical fertilizers in crop production. Soil fertility have been robbed by the application of chemical fertilizer, moreover decline in biodiversity, nutrient and pesticide runoff and have resulted in health and environmental hazards (Boussemart *et al.,* 2013). So, organic Agriculture is a time demand for our country. Sustainable safe and nutritious vegetable production are the major challenges for global food security which make dietary needs and food preferences for an active and healthy life. Moreover, these are one of the most important sources of minerals and nutrients. Diversification and commercialization of crops can be in enhanced in our country through organic vegetable production. Hence, the alternative way is to reduce the use of inorganic fertilizers by recycling the organic wastes as fertilizers (organic farming). Sustainable solid waste management and agriculture can be fulfilled in this way (Balraj *et al.,* 2014). In organic crop production organic matter is supplied by organic manure. A new organic manure or compost is prepared by using cow dung and Shrimp shell powder (chitosan raw material). The organic manure/material preparation can be defined as a method for the complete utilization of the waste, and which also serves as a media for recycling nutrients and also keep away from disposal problem and following environmental consequences (Amar *et al*., 2006). The raw material used for this manure is a very good resource to improving plant productivity.

Chitosan is a linear polysaccharide composed of randomly distributed β-(1→4)-linked D-glucosamine (deacetylated unit) and N-acetyl-D-glucosamine (acetylated unit). Chitosan are structural component of the cuticle of crustacean insect, mollusk and in the cell wall of fungi and plant pathogen (Boonlertnirun *et al.,* 2008). It is made by treating the chitin shells of shrimp and other crustaceans with an alkaline substance (for example, sodium hydroxide). Bangladesh is a world-leading exporter of frozen shrimps and there are abundant raw materials for chitosan production. Chitosan has a wide scope of application in agriculture. Chitosan stimulates plant growth and increase this yield of plants as well as induces the immune system of plants (Boonlertnirun, 2008; Sultana *et al.*, 2017). Chitosan has specific properties of being environmentally friendly and easily degradable. With high affinity and non-toxicity, it does no harm human beings and livestock (Hamed *et al.*, 2016). Chitosan regulates the immune system of plants and induces the excretion of resistant enzyme. In Agriculture, Chitosan primarily used as plant growth regulator, natural seed treatment and as a bio-pesticide substance that boost the ability of plants to defend themselves against fungal infections (Linden *et al*., 2000). Chitosan was found to have a positive effect on growth and development of different crops (Chibu and Shibayama, 2001; Wanichpongpan *et al*., 2001). Chitosan application helps to maintaining quality of postharvest spinach by regulating the elicitation processes and limiting bacterial growth (Methia *et al.*, 2022). Chitosan can increase the yield of plants (Mondal *et al*. 2012), reduce transpiration (Dzung *et al*. 2011) and induce a range of metabolic changes as a result of which, plants become more resistant to viral, bacterial and fungal infections (Al-Hetar *et al.* 2011). Chitosan stimulates key processes of plants on every level of biological organization, from single cells and tissues, through physiological and biochemical processes, to changes on the molecular level related to expression of genes (Limpanavech *et al*., 2008, Hadwiger 2013, Nguyen Van *et al.* 2013). Chitosan has found to enhance plant growth in many crop species; for example, rice (*Oryza sativa* L.) (Boonlertnirun *et al*., 2006), pearl millet (Sharathchandra *et al*., 2004) and the grain yield of Maize (Guan *et al.*, 2009). Seed treatment of maize with chitosan increased the germination index, reduced the mean germination time and improved seedling growth character under low temperature stress (Guan *et al.*, 2009).Application of chitosan on rice plants reduce subsequent leaf damage during drought stress and improved the yield components (Boonlertnirun *et al*., 2007). Chitosan regulates the immune system of plants and induces the excretion of resistant enzymes and thus improves its disease and insect resistant ability (S. H. *et al*., 1995). It has vital effects on agriculture, for example, acting as the carbon source for microbes in the soil, accelerating of transformation the process of organic matter into inorganic matter and assisting the root system of plants to absorb more nutrients from the soil (Ibrahim *et al*., 2015).. Chitosan is absorbed to the root after being decomposed by bacteria in the soil. Application of chitosan in soil, even without chemical fertilizer, can increase the microbial population by large numbers, and transforms organic nutrient into inorganic nutrient, which is easily absorbed by the plant roots (Choi, 2016).

Chitosan can destroy bacterial cell membrane which cause death due to the leakage of intracellular substances (Liang *et al*., 2014).

Shrimp sell powder (Chitosan raw material) can be used as organic manure by composting or direct application in soil. The raw materials are abundant in our country, shrimp processing industry produces over millions tons of waste shell. Peeling process of shrimp involves the removal of the shell from the tail of prawn, increases the total waste production up to 40-45% (Ravi Kumar, 2000). Shrimp shell waste is easily degradable and eco-friendly. A wide range of microorganisms have the ability to degrade chitin by producing chitinases, for nutrition, antagonism and combating parasites (Faramarzi et al., 2009). The biotransformation of waste seems to be the most suitable for replacing artificial fertilizer. It corresponds to the elaboration of beneficial products of natural origin which can be used as bio-fertilizing agent for soil (Taiek et al., 2014) in substitution of artificial fertilizers. Hu et al., 2008 reported that during the composting process, microorganisms alter organic waste materials into compost by breaking down to simple compounds and reforming them into new complex compounds. This process is very cost effective because of the abundance of soil microbes who performs the degradation process (Krishnaveni and Ragunathan, 2014). These microorganisms utilize the complex nutrients of the compost and liberate the essential minerals and elements into soil which becomes easily available to crops and improve their yield (Kalpana *et al*., 2011). Composition of the chitosan raw material (shrimp shell powder) has a very good source of plant nutrients (Isaak, 2016). Chitosan raw material includes high level of Nitrogen (more than 13%) and organic carbon (more than 18%) including P, K, S, Ca, Mg, Zn, B , and it is alkaline in nature (Isaak, 2016). The effect of raw material in plants effect indicates that some growth promoting hormones are available in the raw materials (Isaak, 2017). When chitosan raw material are applied for efficient growth of Crop, decline in organic carbon is arrested and the gap between potential and actual yield is bridged to large extent. Combined application of cow dung and shrimp shell powder supplies essential nutrients to plants and thus, a shift from chemical fertilizers to recycled organic waste will represent a sustainable method of agriculture. When chitosan raw material are applied for efficient growth of Crop, decline in organic carbon is arrested and the gap between potential and actual yield is bridged to large extent.

The objectives of the above study are as follows –

1. To examine the effect of the decomposed shrimp shell powder on growth, yield and nutrient content of Indian spinach.
2. To examine the effect of the decomposed shrimp shell powder on soil chemical properties after harvesting of Indian spinach.

CHAPTER II

REVIEW OF LITERATURE

Now-a-days organic farming is a hot topic. Sustainable agriculture is a big concern, and for this various organic products are introduced in agriculture. Many scientists are working on different organic substances, organic manure, composts, etc. At present the world is looking forward to organic cultivation for sustainable agriculture and also waste management is a burning issue. Various waste products are now used as organic manure or compost. Shrimp shell powder (Chitosan raw material) is a good source of plant nutrient which has influence on plant growth, yield and yield contributing characteristics as well as on soil fertility. Crustacean by-products has excellent biocompatibility, and is also safe and non-toxic. Extensive studies of the effect of chitosan on various crops and soil have been carried out worldwide by various workers. Some of the related papers are reviewed below.

2.1 Effect of different organic manures on vegetables

Different organic materials are readily available in Bangladesh. Organic manure and fertilizers has great role in crop production and soil health. It was observed that organic fertilizer increase crop yield and may act as replacement for synthetic fertilizers.

Ekwealor *et al*., (2020) revealed that the application of different rates of organic manure (cow dung) has a great influence on the growth of *Solanum lycopersicum* L. The study alluded that cow dung can be used to enhance the growth, productivity and yield of tomato in low nutrient soil in the rate of 20 kg ha^{-1} which showed a significant increase in growth and yield of tomato.

Dongyan *et al*., (2020) tested the impacts on soil fertility, plant yield, and plant nutrient content when growing vegetables (Arugula and Radish) at different compost treatments rates (10%, 30%, 50% and 70% v/v) and with synthetic fertilizer. The compost used in this study was produced from food wastes and wood chips. The study revealed that, the impacts on vegetable growth and soil fertility varied exceptionally by the compost amendment rate. The compost can improve C, N, K and Zn at medium to high treatment rates (30% to 70%). Based on the outcomes of the study, it reported that root vegetables will thrive at 50% compost treatment allowing for the replacement of complete synthetic fertilizer use without significant reduction on yields and nutrients. And for leafy green vegetables, the 70 % compost concentration permits the replacement of more than half the total fertilizer usage.

Gyewali *et al*., (2020) reported that poultry manures combined with bone meal and PSB is suitable to cultivate radish.

Akter *et al*.; (2021) conducted an experiment to investigate the effects of organic fertilizer like bio-slurry and inorganic fertilizer on the growth and yield of Indian spinach (*Basella alba L*.). The experiment consisted of six treatments following T_1 - Inorganic fertilizer (100%), T_2 - Inorganic fertilizer (75%) and bio-slurry (25%), T_3 - Inorganic fertilizer (50%) and bio-slurry (50%), T_4 - Inorganic fertilizer (25%) and bio-slurry (75%), T_5 - Organic fertilizer (100%), and T_6 - No organic or inorganic fertilizers (control). Here, bio-slurry was used as a source of organic fertilizer. The vine length was found 40% and 41% higher at 30 and 45 days after sowing, respectively under T_4 treatment compared to control. Overall, the yield and other parameters were found significantly different and the highest yield from T_4 was found significantly 212% higher compared to control. Therefore, the combined application of bio-slurry and inorganic fertilizer can promote the sustainable and eco-friendly production of Indian spinach.

Rahaman *et al*., (2015) did a pot experiment on Indian Spinach in saline soil to evaluate the effect of organic manure on growth of Indian Spinach and reclamation of salinity. The experiment was designed with 4 treatments viz. control (T_0), commercial compost (T_1), poultry manure (T_2), and combination of compost and poultry manure (T_3) were used for this purpose. The experiment revealed a decrease in the pH level from 8.1 to 7.6 and also a decrease in the concentration of electrical conductivity from 7.2 to 4.2 dS m^{-1} at the end of experiment. The positive effects of treatments followed the order: $T_3 > T_2 > T_1 > T_0$. The most effective amendment in reducing sodium adsorption ratio (SAR) in the experimental soils was treatment T_3, where compost and poultry manure were applied together. The yield of biomass was found maximum at T_3, the increase being 166% in comparison with T_0.

Mahabub *et al*., (2014) conducted an experiment to find out the effect of cowdung on the growth, yield and nutrient content of mungbean (*Vigna radiata* L.). The result revealed that the tallest plant, the highest number of leaves plant^{-1}, the highest number of branches plant^{-1}, the minimum number of days required for 1st flowering, the minimum number of days required for 80% pod maturity, the highest number of pods plant^{-1}, the highest number of seeds pod^{-1}, the longest pod, the maximum weight of 1000-seeds, the highest seed yield, the highest stover yield and nitrogen, phosphorus, potassium and sulphur content in seeds were recorded from 10 ton cowdung ha^{-1}, whereas the lowest value was found from control.

2.2 Effect of chitosan and chitosan raw material powder or shrimp shell powder on agriculture

Metwaly *et al*., (2023) conducted a field trial, to evaluate the effectiveness of Micro Carbon Technology TM (MCT–P) and Chitosan (CHI) in improving strawberry cv. Fortuna growth and yield as well as their quality. Results revealed that foliar spraying of chitosan and MCT-P considerably improved strawberry plant growth (i.e., plant height, secondary crown number per plant, leaf number and area per plant, and foliage fresh weight), photosynthetic pigment concentration (chlorophyll a, chlorophyll b, and carotenoids), as well as its yield and quality (early fruit yield, total yield, average fruit weight, fruit firmness, fruit dry matter %, soluble solid content, total sugars (%), ascorbic acid, acidity, and anthocyanin). 1200 mgL^{-1} MCT-P and 1000 mgL^{-1} CHI supplementation showed the most effective concentration for improving all studied characteristics compared to untreated plants. The interaction between CHI and MCT-P had an effective influence on all examined characteristics of strawberry. Experiment findings recommended to spray strawberry cv. Fortuna with 1200 mgL^{-1} MCT-P plus 1000 mgL^{-1} CHI every two weeks, from 60 days after transplanting until two weeks before the end of harvesting season for the best fruit yield and quality.

Lyalina *et al*., (2023) conducted an experiment to evaluate the effects of chitosan as a seed primer on Lettuce. Seed germination, plant morphology, and biochemical indicators of lettuce at different growth stages were evaluated. Under the 0.1 mg ml^{-1} CH treatment, earlier seed germination was observed compared to the control. Increased root branching was found, along with 100% and 67% increases in fresh weight (FW) at the 24^{th} and 38^{th} days after sowing (DAS), respectively. Moreover, significant increases in chlorophyll and carotenoid content in lettuce were observed at the 10th DAS compared to the control. There were no significant differences in the activity of phenylalanine ammonia-lyase, polyphenol oxidase, β-1,3-glucanase, and chitinase observed at the 24th and 38th DAS. So, results suggested that seed priming with chitosan could increase the yield and uniformity of plants within the group.

Wan Ahmad Sofian *et al*., (2022) reported that the highest length of fruits was achieved at 75 ppm and the highest average diameter of fruit at 100 ppm chitosan application in cucumber. The impact of chitosan on the total number of fruits per plant and the total weight of fruit showed a positive result. The best performance in controlling diseases that affect fruits and leaves was observed when chitosan applied at the concentrations of 75–100 ppm. Foliar applications of chitosan resulted in increased vegetative growth, better fruit quality and plant disease control in cucumber compared to untreated control plants.

Methia *et al*., (2022) carried out a study on spinach to analyze the capacity of chitosan to improve postharvest management of spinach. In this study, harvested spinach leaves were dipped in distilled water, 1% (v/v) acetic acid, and 0.1 and 0.5% (w/v) chitosan. The leaves were then examined for morphological, physiological, and molecular parameters following each treatment on days 0 and 3 after incubation at room temperature with a 12/12-h photoperiod. The results indicated that the application of 0.1% (w/v) chitosan solution to postharvest spinach delayed the decaying process, possibly due to the suppression of bacterial growth. So, the experimental results indicated that chitosan treatment has a role in maintaining quality of postharvest spinach by regulating the elicitation processes and limiting bacterial growth.

Nerdy *et al.,* (2022) reported that Crustacean shell waste can be processed into chitosan. Chitosan or crustacean by products is valuable and can be used as a natural adsorbent against heavy metals and dyes for wastewater treatment in several industrial sectors and has a great response of all plant growth and yield parameters.

Abirami *et al*., (2021) conducted an experiment to evaluate the potential effects of shrimp shell waste compost on the growth characteristics of okra (*Abelmoschus esculents L.*). The growth parameters of okra was analyzed in shrimp shell compost and also along with other composts (SSC + CD and SSC + CD+CP). Results of this study indicate that, nitrogen, phosphorus and potash content were increased in soil when the shrimp shell composts (SSC) with adding chitinase producing bacterium (*Bacillus licheniformis* SSCL10) was applied compared with control. The maximum plant growth performances were found in the SSC+CD (cow dung) compared to combination of CP (coir pith), shrimp shell composts (SSC) alone and control. Outcomes revealed that, shrimp shell compost can be used as supplements for other compost to induce plant growth performances.

Roja *et al*., (2021) observed that, irrespective of varieties, the foliar application of chitosan at 75 ppm significantly increased the biometric as well as yield related attributes of mulberry over other concentrations. Among the three varieties, VI showed more response to chitosan application than G4 and MR 2. Chitosan showed marked effect on VI variety of mulberry. Significantly increased shoot length (170.67 cm), number of shoots per plant (9.03), number of leaves per shoot (29.48), leaf area (220.26 cm^2) and leaf area index (2.72) were observed in VI variety at 75 ppm chitosan application compared to control. The application of chitosan at 75 ppm significantly enhanced the yield traits viz. weight of 100 leaves (448.10 g), leaf shoot ratio (1.45) and leaf yield (14.01 MT ha^{-1} $harvest^{-1}$) in VI variety of mulberry.

Ahmed *et al.,* (2020) conducted a field experiment to examine the effect of chitosan-raw- materials on yield maximization of BRRI dhan 49 laid out in RCBD consisting four treatments with five replications. The treatment combinations were: 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 tha^{-1}. Dry matter of a treated single seedling was increased by 25.88 mg on average. Result indicated that, the total number of tillers/hill the treatments were found as $T_3 > T_4 > T_2 > T_1$. It revealed that the application of chitoan-raw-materials in soil increases the total tillers $hill^{-1}$.

Shehzad *et al*., (2020) observed the effects of individual Chitosan application on growth, physiological processes and anti-oxidative defense system of sunflower under drought stress. Various doses of Chitosan (0, 0.1, 0.2, 0.3, 0.4, 0.5 gL^{-1}) were foliar applied to evaluate their role in improving plant biomass, water status and total chlorophyll in drought-induced seedlings of sunflower. It was observed that chitosan

(0.28 gL^{-1}) doses impacted more pronounced at vegetative than reproductive stage. The outcome also revealed that positive effects of Chitosan application were related to improved physiological and metabolic processes to improve yield and quality of sunflower under drought stress.

Sultana *et al*., (2020) conducted a field experiment on BRRI dhan29 to investigate the residual effect of chitosan raw material powder. Experiment comprised of different treatment combination of CHT powder and N fertilizer. The total nitrogen content, soil pH, organic carbon and organic matter status in the post-harvest-soils were increased due to the residual effect of CHT powder in rice growing soils. The maximum value of the pH (7.01), organic carbon content (0.72%), and organic matter content (1.24%) in the 16 post-harvest soils were found in the treatment T_4 (CHT powder @4.0 t ha-1 (applied in the previous experiment) + 2/3rd of recommended N fertilizer) and lowest values were observed in the control treatment (CHT powder @ 0 t ha^{-1} (applied in previous experiment) + recommended N Fertilizer).

Khatri *et al*., (2020) conducted a study with the combination of Aloe vera gel and chitosan, as edible coatings, in extending the post-harvest shelf-life of tomato (*Solanum lycopersicum Mill.*). They revealed that combination treatment of Aloe vera gel and chitosan showed the best efficiency in delaying the ripening process of tomato and surprisingly extended the fruit shelf life up to 42 days.

Esyanti *et al*., (2019) reported that physiological parameters, such as increment of height and leaves number, and chlorophyll content indicated an improved growth process in chitosan treated plants compared to the control. Plant resistance to *Phytophthora* infection was also investigated following chitosan application to highly (CM334), moderately (LABA), weakly (LADO) resistant and susceptible (15080) cultivars of chilli.

Muley *et al*., (2019) revealed that chitosan (75 mg L^{-1}) and oligo-chitosan (50 mg L^{-1}) can augment plant growth and induce defense mechanism for drought stress tolerance in potato. They found, improvement in shoot height and number of nodes after foliar spray of chitosan and oligo-chitosan at 50–75 mg L^{-1} in potato.

Parvin *et al*., (2019) conducted an experiment on tomato by using different concentration of chitosan. The results revealed that, plant high, number of flower clusters plant^{-1} and flowering duration of tomato increased when chitosan was applied. The longest Plant was obtained in T_4 treatment (74.00 cm) followed by T_9 and T_{10} at 80 DAT whereas, the shortest plant hight (62.75) was observed in control (T_0). The maximum number of flower cluster plant^{-1} was recorded in both T_5 and T_7 treatments, while the minimum number was found in control.

Ananthaselvi *et al*., (2019) investigated the effect of foliar spray of chitosan on morphological, growth and flowering characters of the African marigold under induced drought condition. The experiment consists of three levels of water stress viz. 100%, 70% & 50% field capacity and three levels of chitosan sprays i.e. 0, 0.2 g & 0.4 g . The outcome of the experiment indicated that 70% field capacity with 0.2 g of chitosan improved morphological parameter like plant height (cm) of African marigold.

Deotale *et al*., (2019) did a field experiment to find out the effect of different concentration of chitosan and IBA @ 25, 50, 75, 100, 125 ppm. In this experiment, the foliar spray was given at 30 DAS on soybean. The increase in morphological characters like plant height, number of branches and leaf area were recorded at 25 ppm concentration of chitosan.

Priyaadharshini *et al*., (2019) carried out a field experiment to study the effect of chitosan nano-emulsion in pearl millet under water deficit condition. Foliar spray of 0.1% chitosan nano-emulsion along with control (untreated) was done at flowering stage of pearl millet under moisture stress condition. Physiological traits on gas exchange parameters (photosynthetic rate, stomatal conductance, and transpiration rate and leaf temperature), chlorophyll index, relative water content and yield attributes were recorded after foliar spraying of chitosan. The results indicated that the treatment with chitosan causes reduction in stomatal conductance thus limiting the photosynthesis, transpiration rate and raise in leaf temperature than unsprayed plants. The yield increased significantly in treated plants than control under drought condition. So it is reported that, foliar spray of chitosan plays an important role in alleviating the harmful effects of water stress by improving the plant water status and yield.

Rahman *et al*., (2018) conducted a study on strawberry plant, that revealed that foliar applications of chitosan on strawberry significantly increased plant growth and fruit yield (up to 42% higher) compared to untreated control. Increased fruit yield was attributed to higher plant growth, individual fruit weight and total fruit weight plant^{-1} due to the chitosan application. Moreover, the fruit sprayed with chitosan also had significantly higher contents (up to 2.6-fold) of carotenoids, anthocyanins, flavonoids and phenolics compared to control. Total antioxidant activities in fruit of chitosan treated plants were also significantly higher (ca. 2-fold) ($p< 0.05$) than control.

Islam *et al*., (2018) conducted an experiment, in which four levels of oligochitosan were used with control to optimize the level for obtaining maximum yield in tomato and chilli. From the outcomes, it showed that in case of tomato 50 ppm chitosan level was found optimum in terms of yield (2.48 kg plant^{-1}). As for chilli, 75 ppm chitosan level was found optimum in yield (333.01 g plant^{-1}).

Pandey *et al*., (2018) reported that chitosan is emerging as a potential agent in agriculture, which can be used in enhancing defence mechanism of plant, as growth promoter, as antimicrobial agent, and as a soil conditioner. Beside this, chitosan can be used as carrier for improving nutrient delivery, increasing water use efficiency and as absorbent of heavy metals.

Parvin *et al*. (2018) studied the effect of irradiated chitosan coating on postharvest preservation of tomato. Irradiated chitosan (40 kGy) solution of various concentrations (500, 750, 1000, 1500 and 2000 ppm) were applied on tomato for post-harvest preservation. The results showed that application of 1500 ppm chitosan solution performed better in extending the shelf-life of tomato as compared to the control and other treated samples.

Al-Tawaha *et al*., (2018) conducted an experiment to find out the effect on the quality and productivity of barley by the fertilizer and chitosan application. Chitosan, in three different concentrations (0, 5, and 10 gL^{-1}), was applied. However, other parameters, like as the number of grains, number of spikes, and number of grains were also found to be influenced by the chitosan treatment. Significant variation (P< 0.01) were found between the lines in the presence and absence of chitosan application. The foliar treatment of 10 g L^{-1} chitosan to barley plants at the tillering stage produced the highest number of grain yield, number of spikes, and grains spike^{-1}. Moreover, the grain quality, particularly in case of protein and starch, was found to be enhanced significantly over control.

Xu *et al.,* (2018) observed short-term (35 days after transplanting) effects of chitosan, applied as a soil amendment at 0%, 0.05%, 0.10%, 0.15%, 0.20%, or 0.30% (w/w), on lettuce (*Lactuca sativa*) growth, chlorophyll fluorescence, and gas exchange were evaluated in a growth chamber study. Chitosan at 0.05%, 0.10%, and 0.15% increased leaf area and leaf fresh weight in a dose corresponding manner respectively. Only chitosan at 0.05% and 0.10% increased leaf dry weight from 3.42 to 4.37 and 4.35 g, respectively, but chitosan at 0.30% decreased leaf number, area, fresh and dry weight. Chitosan at 0.10%, 0.15%, 0.20%, and 0.30% increased leaf chlorophyll index. Chitosan application at 0.20% and 0.30% increased leaf maximum photochemical efficiency and photochemical yield, and chitosan applied at 0.10%, 0.15% 0.20%, and 0.30% increased leaf electron transport rate. The observed outcomes indicated that chitosan, at appropriate application rates, enhanced lettuce growth, and might have potential to be used for sustainable production of lettuce.

Behboudi *et al*., (2018) observed the effect of chitosan in grain yield and grain weight of barley under drought condition. They reported that, that chitosan uses significantly improved the number of grain per spike and grain yield as compared to that in control. The maximum 1000-grain weight was obtained with the foliar treatment of chitosan in the well-watered plant and they also noticed that the chitosan application in soil considerably improved the 1000-grain weight in plants under water stress than that of control.

Issak and Sultana (2017) conducted an experiment to observe the Role of chitosan powder on the production of quality rice seedlings of BRRI dhan29. The experiment was done in the field of Sher-e-Bangla Agricultural University, Dhaka. The treatments used in the study were as follows: T_1 = 100 g chitosan (CHT) powder m^{-2} , T_2 = 200 g CHT powder m^{-2} , T_3 = 300 g CHT powder m^{-2} , T_4 = 400 g CHT powder m^{-2} , T_5 = 500 g CHT powder m^{-2} , T_6 = 0 g CHT powder m^{-2} . Results revealed a significant variation in the seedlings height, biomass production, dry matter production and chemical properties of the seedbed soils due to the application of chitosan powder in the seedbed. The maximum seedlings height, fresh weight, oven dry weight was observed in the treatment T_4 and the minimum level in T_6 (control). In case of soil chemical properties, the maximum level of organic carbon, organic matter and soil pH was recorded in the treatment T_5 and the minimum level in the treatment T_6 (control).

Chitosan powder increased the level of organic matter in soil in a dose dependent manner. Quality of the Boro rice seedlings were improved by application of chitosan powder and the seedlings strength were also increased in a dose dependent manner. Good quality Boro rice seedlings having more chlorophyll level and seedlings strength were observed under chitosan application than the control. Results indicated that treatment T_4 shows the superior results than other treatments. These results indicated that this might be happened due to some nature of soil alkalization and other some macro-micro nutritional supplementation which may improve the seedlings strength.

Sultana *et al*., (2017) investigate the effect of oligo-chitosan (O. chitosan) on growth, yield attributes and economic yield of tomato and egg-plant under Bangladesh conditions. Three levels of oligo-chitosan concentration viz. 0 (control), 60 and 100 ppm were used. Oligo chitosan was sprayed five times after sowing. The results indicated that plant height and number of flowers plant^{-1} increased with increasing concentration of chitosan spray till 100 ppm. Foliar spray with 60 and 100 ppm O-chitosan were effective in increasing total yield plot G_1 of tomato (41.67 and 38.30 kg, respectively) than control (22.79 kg). The acidity and protein content in tomato has been significantly ($p<0.05$) decreased from plant treated with 60 ppm chitosan whereas, 100 ppm chitosan application significantly ($p<0.05$) increased protein content in eggplant. The powerful antioxidant (phenolic content) component was found to be increased ($p<0.05$) significantly with chitosan application in eggplant but decreased only with lower dose in tomato. It was concluded that the growth and functional components of tomato and eggplant enhanced when the foliar application of oligo-chitosan was done at early growth stage.

Rabbi *et al*., (2016) carried out experiment in which four level of concentrations of chitosan viz., 0 25, 50, 75 and 100 ppm with untreated control was applied at 30 and 40 DAS on mungbean plant. Results revealed that foliar application of chitosan @ 50 ppm significantly enhanced morphological characters such as plant height, number of branches, number of leaves and leaf area plant $^{-1}$.

Islam *et al*., (2016) carried out an experiment to investigate the effect of foliar sprays of chitosan on summer and winter tomato, summer mungbean, maize and Aman and Boro rice. Chitosan was sprayed at four concentrations at the rate of 25, 50, 75 and 100 ppm for two times at vegetative and flowering stages of tomato and mungbean. For maize and rice, chitosan was sprayed three times at vegetative and flowering stages at concentration of 25, 50 and 75 ppm for rice and 50, 75, 100 and 125 ppm for maize. The outcome showed that, increase in physiological character like reproductive efficiency was observed best at 75 ppm for summer and winter tomato. Highest physiological parameters were observed more at 50 ppm concentration of chitosan in summer mungbean. For maize more physiological characters were observed at 100 ppm concentration of chitosan application. For boro and aman rice physiological characters were increased at 50 ppm concentration of chitosan application.

Anusuya *et al*., (2016) reported that the growth parameters (shoot height, leaf number/plant, and plant fresh weight) were increased when was applied on turmeric plants. Foliar application of chitosan induced the activity levels of defense enzymes in turmeric plant such as protease inhibitors (PI), β-1, 3 glucanases, peroxidases (PO) and polyphenol oxidases (PPO) in the leaves and rhizomes of turmeric plants. Chitosan treatment thus results in high yield and cur cumin content of turmeric.

Ahmed *et al*., (2016) observed the effect of foliar application of chitosan. In this experiment, two concentrations of chitosan @ 250 and 500 ppm were sprayed on novel orange. Increase in morphological parameters like shoot length, leaves number and leaf area were recorded at concentration of 500 ppm chitosan.

Malekpoor *et al*., (2016) conducted a study to find out the effect of chitosan on morphological and physiological characteristics of sweet basil (*Ocimum basilicum*) under different irrigation regimes. Treatments combinations were as follows, control, 0.0, 0.2 and 0.4 gL^{-1} of chitosan applied to plants under normal irrigation, and slight and mild drought stress. The content of photosynthetic pigments and growth parameters were decreased due to drought stress. Foliar application of chitosan, in particular level of 0.4 gL^{-1} increased plant growth under stressed or non-stressed conditions compared with untreated plants.

Sultana *et al*., (2015) conducted a field experiment on rice plant using oligo chitosan. This experiment was designed with four different concentrations of oligo chitosan viz. 0, 40, 80 and 100 ppm and four times foliar spray after germination. The result indicated that plant height does not have any statistically significant differences between control and 40 ppm oligo-chitosan sprayed plants. But in case of 80 and 100 ppm oligo-chitosan sprayed rice plants show significant differences compared to control. Moreover, it was observed that straw yield show significant differences between control plants and foliar sprayed chitosan plants. The highest straw yield was obtained under 100 ppm oligo-chitosan and lowest straw yield was obtained under 0 ppm oligo-chitosan (control).

Chamnanmanoontham *et al*., (2015) conducted an experiment to observe the effect of combination of the degree of deacetylation (DD), molecular weight and concentration of chitosan on the rice seedling growth. It was observed that, oligo-chitosan with an 80% DD applied at 40 mgL^{-1} significantly enhanced the vegetative growth, in terms of the leaf and root fresh weights and dry weights of rice seedlings compared to the control. Chitosan had enhanced the plant growth of rice seedlings through multiple and complex networks between the nucleus and chloroplast.

Martínez *et al*., (2015) reported that seeds treated with chitosan @100 mg L^{-1} stimulated shoot length and dry matter of seedlings grown in saline media. They also observed that, treatment with chitosan lowered malondialdehyde and increased proline levels. Therefore, Chitosan concentrations enhanced the activities of catalase and peroxidase enzymes, although a higher effect was obtained with chitosan application @ 500 mg L^{-1}.

Ibraheim *et al*., (2015) conducted an experiment at El-Khattara Experimental Farm, Faculty of Agriculture, Zagazig University, Sharkia Governorate, Egypt, to study the effect of nitrogen fertilization and foliar spray with chitosan on growth, yield and fruits quality of summer squash plants grown in sandy soil. This experiment included nine treatments combinations where three rates of nitrogen (45, 60 and 75kg $feddan^{-1}$) and three concentrations of chitosan (0.0, 0.05 and 0.10 gL^{-1}) were applied. The results revealed that the fertilization of summer squash plants with N at 75 kg $feddan^{-1}$ significantly enhanced plant growth characters, yield and its components, and nutrients (N, Fe, Cu, Mn and B) but, T.S.S. (%), P and K contents in fruits were not significantly affected by it. Whereas, spraying with chitosan at 0.10 gL^{-1} significantly increased plant growth characters, yield and its components, T.S.S. %, N and P content. On contrary, chitosan application decreased Fe, Zn, Cu and B content in fruits. In addition, the result revealed that the interaction treatments between N at 75 kg $feddan^{-1}$ and spraying plants with chitosan at 0.10 gL^{-1} gave the highest values of plant growth, yield and its components, N as well as P content in summer squash fruits.

Kananont *et al.*, (2015) conducted an experiment with Fermented chitin waste (FCW). Experiment comprised 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 outcomes revealed that FCW @ 1% the grain yield differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

Agbodjato *et al*., (2015) conducted a study to observe the combined effects of three plant growth promoting Rhizobacteria (*Azospirillum lipoferum*, *Pseudomonas fluorescens* and *Pseudomonas putida*), chitosan (a bio stimulating molecule) and half or complete dose of nitrogen-phosphorus-potassium (NPK) and urea in maize. Outcomes indicated that the combination of *P. putida* along with chitosan and half dose of NPK-Urea increased height and circumference of maize plant.

Salachna and Zawadzinska (2014) conducted an experiment to analyze the effect of chitosan molecular weight on growth and yield of flowers and corms of potted fressia (an ornamental plant). Fressia corms were soaked in 0.5% chitosan solution with low molecular weight (2 kDa), medium molecular weight (50 kDa) and high molecular weight (970 kDa) respectively. The high molecular weight (970 kDa) showed increase in morphological characters like plant height, number of leaves and days to flowering.

Nguyen Toah and Tran Hanh (2013) conducted an experiment on rice applying chitosan treatment. The field data of their studies showed that the yields of rice significantly increased (~31%) after applying chitosan solution. So it suggested that, applying chitosan increased rice production and reduced cost of production significantly.

El-Miniawy *et al*., (2013) carried out an experiment to find out the effect of foliar spray of chitosan on strawberry. Treatment combination was as follows, foliar application of chitosan concentration viz., 2.5 or 5.0 ml L^{-1} with different number of application i.e. once, twice and three times was done on strawberry. The result reported that three times foliar spraying of chitosan at 5.0 ml showed significant increase in morphological characters like plant length, number of leaves per plant and leaf area as compared to control(untreated).

Mondal *et al*., (2013, b) conducted an experiment to observe the effect of foliar application of chitosan on mungbean plants. In this study, five treatments were used, concentrations of chitosan viz., 0, 25, 50, 75 and 100 ppm were applied at 25 and 35

DAS. Experimental data findings indicated that 50 ppm chitosan increase growth parameters like plant height, number of branches, number of leaves and leaf area plant $^{-1}$.

Sathiyabama *et al.,* (2013) carried out an experiment to analyze the effect of foliar application of chitosan on tomato plants. 0.1% (m/w) of chitosan was used for this study. The findings reported that there was an increase in morpho-physiological characters like number of flowers and fresh weight in chitosan treated plants than control.

Mondal *et al*., (2013) reported that foliar application of chitosan at early growth stages improved the plant height, leaf number plant^{-1} , leaf length and breadth, leaf area plant $^{-1}$, physiological (total dry mass plant^{-1}, absolute growth rate and harvest index) parameters and yield components thereby increased seed yield of maize. The highest seed yield was obtained at 100 and 125 ppm of chitosan application in maize. So it is revealed that, foliar application of chitosan at 100 ppm may be used at early growth stage for getting maximum seed yield in maize.

Berger *et al.,* (2013) revealed the potential of rock biofertilizer mixed with earthworm compound inoculated with free living diazotrophic bacteria and C. elegans (Fungi chitosan) for plant production and nutrient uptake. The bio-fertilizer, such as Fungi chitosan may be an alternative for NPK fertilization that slows the release of nutrients, favoring long-term soil fertility.

Abu-Muriefah, S.S. (2013) conducted an experiment to investigate the effect of chitosan on common bean. Chitosan was applied @ 100, 200 and 400 ppm. The result revealed that application of chitosan @ 200 ppm showed significant increase in plant growth viz., number of branches, leaf number, plant height and leaf area plant^{-1}.

Mondal *et al*., (2012) investigated the effect of different concentrations of chitosan viz., 0, 50, 75, 100 and 125 ppm on okra. The result revealed that, morphological parameters like plant height, leaf number of okra had significantly increased by spraying of chitosan @ 100 or 125 ppm at 25, 40 and 55 DAS of okra.

El-Tanahy *et al*., (2012) conducted an experimental trial in the two successive seasons to investigate the effect of Chitosan, organic (cattle manure and compost) and inorganic fertilizers (NPK) on vegetative growth and productivity of cowpea plants. Chitosan solution at concentrations of 1, 3 and 5 % was sprayed three times after 30, 45 and 60 days from seed sowing until runoff. Data indicated that the use of the highest concentration of Chitosan (5%) with the application of the inorganic fertilizer gives the best effect on plant vegetative growth (plant height, number, fresh and dry weights of leaves and shoots), yield and its component (pod length, weight and diameter and number. of seeds and seed yield) and seeds quality (total protein, total carbohydrates N, P and K), whereas the lowest effect was recorded by using the Chitosan (1%) with the application of the organic fertilizer of the cattle manure. So, results revealed that, there is a positive relationship between increasing the applied concentration of Chitosan.

Farouk *et al.*, (2012) reported that foliar-application of chitosan in cowpea, in particular 250 mg L^{-1}, increased plant growth, yield and its quality as well as physiological constituents in plant shoot under stressed or non-stressed conditions as compared to untreated plants. Moreover, the severity of cowpea plants damaged from water stress was reduced by 250 mg L^{-1} chitosan application.

Jiao *et al*., (2012) studied the effects of exogenous chitosan (CTS) on physiological characteristics of potatoes (variety– Favourite) under drought stress and rehydration. Exogenous CTS was sprayed at 50, 100 and 200 mgL^{-1} of exogenous CTS on potato leaves. Result indicated chitosan promoted the recovery of these physiological indicators after a rehydration period. Among of the three treatments, 100 mgL^{-1} of CTS alleviated drought stress the best. Altogether, it was observed that exogenous CTS could relieve drought stress damage in young potato plants by enhancing their antioxidation ability, increasing the activities of protective enzymes and regulating the content of osmotic regulatory substances.

Van Toan *et al*., (2012) reported that chitosan produced from shrimp shells using dilute acetic acid proved effective in controlling plants infection by microbial agents leading to higher yields of rice. Yield of rice significantly increased (~31%) after applying chitosan solution. So, it indicated that applying chitosan increased rice production and reduced cost of production significantly.

Berber *et al*., (2012) carried out a pot experiment in an open greenhouse on rice with various application of chemical fertilizer and chitosan. The findings revealed that all studied traits of inoculated and non-inoculated rice plants applied with various application methods were not significantly different. Chemical fertilizer application in combination with chitosan did not significantly differ from application of chemical fertilizer alone on morphological attributes like as leaf greenness, plant height, dry matter, grain yield and panicle numbers but significantly differed from those unapplied both chemical fertilizer and chitosan. Nevertheless, seeds of dirty panicle disease were significantly affected by various application methods. The lowest number of dirty panicle infestation were obtained from application of chemical fertilizer in combination with chitosan whereas no application of both chemical fertilizer and chitosan showed negative effect on controlling dirty panicle disease in inoculated and non-inoculated rice plant.

Chookhongkha *et al*., (2012) observed that the seedlings grown in the soil mixed with 1.0% (w/w) high MW of chitosan presented the greatest growth rate and chlorophyll content, and a higher number of dark green leaves followed by medium and low MW of chitosan at 30 days after transplant (DAT) of rice plants. A comparison of chitosan concentrations at 0.5 and 1.0% (w/w) on the growth and seed productivity was done in the green house. Results revealed that, the greatest seed yield indicated by fruit fresh weight plant^{-1}, fruit numbers plant^{-1}, seed numbers fruit^{-1}, and seed weight plant^{-1} was observed in the plants grown in the soil treated with 1.0% high MW of chitosan.

Mondal *et al*., (2011) conducted a pot experiment at the pot yard of Bangladesh Institute of Nuclear Agriculture, Mymensingh during the period from April to June 2011 to investigate the effect of Chitosan application on morphological characters, growth and economic yield in Indian spinach. They noticed that application of Chitosan had a profound influence on morphological characters such as plant height, branch and leaf number, physiological characters such as specific leaf weight (SLW), chlorophyll content in leaves and nitrate reductase activity (NRA) in leaves and yield characters such as leaf area (LA), leaf and stem fresh weight as well as total fresh weight. The experiment was consist of five levels of Chitosan concentrations viz., 0 (control), 25, 50, 75 and 100 ppm and Chitosan was sprayed two times of 15 and 25 days after sowing respectively. The highest plant height and leaf number plant $^{-1}$, chlorophyll and NRA were observed in 100 ppm followed by 75 ppm Chitosan. The highest number of branches plant^{-1}, LA plant $^{-1}$, SLW, leaf and stem fresh weight as well as total fresh weight was observed in 75 ppm followed by 100 ppm application of Chitosan. When Chitosan was sprayed @ 75 ppm the economic yield of Indian spinach like as leaf and stem fresh weight as well as total fresh weight was the highest. So, results suggested that, application of Chitosan @ 75 ppm was optimum for maximizing plant growth and development of Indian spinach.

Abdel-Mawgoud *et al*., (2010) carried out experiment to analyze the effect of foliar application of chitosan on strawberry plants. Chitosan sprays were given three times starting from ten weeks after transplanting with four weeks intervals @ 0, 1, 2, 3 and 4 $cm^3\ L^{-1}$. Plant height, number of leaves, fresh and dry weights of the leaves and yield components (number and weight) were improved with Chitosan application. The responses were positively related to the applied concentrations. The highest peak recorded with concentration of 2 $cm^3\ L^{-1}$ then started to decline with higher application of concentrations but, those were still significantly higher than control. Fruit quality in terms of average weight of individual fruits and TSS performed the similar trends. The result indicated that the increase in morphological characters like plant height, dry weight and number of leaves were found significant in 2 $cm^3\ L^{-1}$ concentration in strawberry plants.

Ziani *et al*., (2010) revealed that seeds treated with chitosan resulted in a better growth of the seedlings (e.g. longer and better developed radicle and greener hypocotyls) of tomato and had lower chance of being infected by fungi in comparison with the untreated seeds. The enhanced growth improvement by chitosan could be related to the incorporation of nutrients (nitrogen) from chitosan.

Sultana (2010) from BAEC, Bangladesh reported that chitosan plays a significant role on growth and productivity of Maize *(Zea mays* L.) Plants on which the oligochitosan was applied for its potential use as plant growth promoter. The application of oligochitosan (molecular weight 7,000 Da) as foliar spraying @ 25, 50 and 75 mgL^{-1} was done on maize. The findings revealed that the application of oligochitosan at the concentration of 75 mgL^{-1} plays a significant role in terms of weight of cob and weight of seeds per Maize and ultimately maize yield.

Guan *et al*., (2009) reported that application of oligo-chitosan increase mineral uptake of maize and stimulated the growth of maize seedlings. Spraying oligo- chitosan with concentration of 60 mgL^{-1} showed a positive effect of chitosan on the growth of roots, shoots and leaves of several crop plants. Chitosan application increased shoot height and root length in maize plants under low temperature compared to that of the control.

El-Tantawy *et al*., (2009) carried out an experiment to analyze the effect of organic manure, goat manure and spraying with amendment substances like chitosan on tomato plants. They noticed that tomato plants fertilized by spraying of chitosan significantly increased all vegetative parameters (plant height and number of both branches and leaves/plant), fresh and dry weight of different plant organs (roots, branches, leaves, and total of both fresh and dry weight of plant), photosynthetic pigments, yield/plant and marketable yield. Moreover, chitosan application also decreased the diseased yield. On the other hand, pH and TSS (%) were not significantly affected by the treatments. The findings revealed that there was positive effect on morphological characters like plant height, number of branches and leaves per plant observed by chitosan spray.

Asghari-Zakaria *et al*. (2009) observed that when 500 mg/l of soluble chitosan was applied in vitro resulted in improved acclimatization of plantlets in the greenhouse as expressed by significant ($P<0.05$) increased the shoot fresh weight, mini tuber number and yield, compared to the control but lower concentrations of chitosan did not significantly affect this trait ($P< 0.05$). The 5 and 15 mgL^{-1} of soluble chitosan application was observed to lead to a significant increase in root fresh and dry weight of in vitro plantlets, whereas, higher concentrations, especially 500 mgL^{-1} of chitosan application decreased root fresh weight of in vitro plantlets of potato.

Limpanavech *et al*., (2008) conducted an experiment to analyze the effects of chitosan molecules on *Dendrobium* "Eiskul" floral production. The study was designed with six types of chitosan molecules, P-70, O- 70, P-80, O-80, P-90, and O-90. Compared to the non-chitosan treated controls, Chitosan molecule O-80 induce early flowering at all concentrations tested, viz. 1, 10, 50, and 100 mgL^{-1} and during the 68 weeks it increased the accumulative inflorescence number in *Dendrobium*..

Gornik *et al*., (2008) evaluate the effect of treatments to grape vine cuttings with chitosan on their rooting, subsequent plant development and reaction to drought stress. Biochikol 020 PC solution was used at concentrations of 0.5, 1 and 2% for 24 hours at 25^0 c. The findings revealed that the growth of cuttings was stimulated when biochikol 020 PC applied at 1%, by increasing number of internodes in comparison with control.

Boonlertnirun *et al*., (2008) carried out an experiment on chitosan application on rice. The four treatments were as follows, T_1 - control (no chitosan application), T_2 - seed soaking with chitosan solution, T_3 - seed soaking and soil application with chitosan solution and T_4 - seed soaking and foliar spraying with chitosan solution. The results indicated that chitosan application by seed soaking and then soil application stimulates the growth and increases yield of plants over the other treatments of rice plants.

Bhuvaneswari and Chandrasekharan *et al*., (2008) reported that varying chitosan application methods did not affect the tiller numbers per plant of rice. The treatment combination of this study were as follows, Tr_1- no chitosan application (control), Tr_2- seed soaking with chitosan solution Tr_3- seed soaking and soil application with chitosan solution and Tr_4- seed soaking and foliar spraying with chitosan solution. The maximum tiller numbers obtained from treatment Tr_3 (seed soaking in chitosan solution before planting and soil application), however did not differ significantly from the control.

Boonlertnirun *et al*., (2007) carried out a greenhouse experiment to investigate the effect of chitosan on drought recovery and grain yield of rice under drought conditions. Reports revealed that the application of chitosan before drought gave the highest yield and yield contributing character and also showed good recovery of rice plants in case of drought.

Boonlertnirun *et al*., (2006) observed that the application of polymeric chitosan by seed soaking before planting followed by four foliar sprayings of chitosan doses throughout cropping season significantly increased the number of tillers per plant and yield of cultivar Suphan Buri compared to control.

Lee *et al*., (2005) investigate the effects of chitosan on the productivity and nutritional quality of soybean (*Glycine max* L.) sprouts. Soybean seeds were soaked in solutions containing 1,000 ppm chitosan of low (<10 kDa), medium (50 to 100 kDa), and high (>1,000 kDa) molecular weight. Within 1 day of treatment, a significant increase in respiration, 5%, was observed in the sprouts treated with high molecular weight chitosan. Chitosan also effectively increased the growth of the sprouts. The growth-improving effects of chitosan were proportional to the molecular weight of the chitosan molecule used in the experiment. Surprisingly, chitosan application did not result in any significant reduction in vitamin C content or postharvest chlorophyll formation, traits that determine the nutritional and marketing values of soybean sprouts. Results revealed that soaking soybean seeds in a solution of chitosan, especially of high molecular weight, may effectively enhance the productivity of soybean sprouts without adverse effects on the nutritional and postharvest characteristics.

Bolto *et al*., (2004) conducted a study on Ion exchange for the removal of natural organic matter and found that CHT (chitosan) can increase the microbial population and transforms organic nutrient into inorganic nutrient which is easily absorbed by the plant roots.

Ouyang and Xu (2003) conducted an experiment with Chinese cabbage (*Brassica campestris*) cv. Dwarf hybrid No.1 and reported that when seed dressed with chitosan at the rate of 0.4-0.6 mg g^{-1} seed and leaf sprayed 20-40 micro gL^{-1} plant height, fresh weight and leaf area was increased.

Hong *et al*., (1998) reported that chitin or it’s derivatives like chitosan improves the durability and resistance of the plant, makes it not easily infected by germs, not proliferate even infected, and cures the disease by itself. Moreover, application of chitosan in agriculture can reduce the use of chemical fertilizer, and increases the production of different kinds of plant by 15-20%.

CHAPTER III

MATERIALS AND METHODS

The experiment was undertaken at the net house of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December, 2020 to March, 2021 to investigate the growth and yield of Indian spinach by using shrimp shell powder and also soil nutrient content after harvesting the crop. Materials used and methodologies followed while conducting the experiment have been described in this chapter.

3.1. Experimental period

The experiment was carried out during the period from December 2020 to March 2021 in Rabi season.

3.2. Description of the experimental site

3.2.1. Geographical location

The experiment was conducted in the net house of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207. The experimental site is geographically situated between 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., 1988 a). 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., 1988 b). For better understanding, the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3. Soil

The soil of the experimental field belongs to AEZ-28 'The Madhupur Tract' (FAO, 1988) and it also belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Top soil was silty clay in nature and having distinct dark yellowish brown mottles. Soil pH ranges from 5.4–5.8(Anon., 1989). 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 field of Sher-e-Bangla Agricultural University (SAU) Farm. The soil analysis 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 site

Morphological features	**Characteristics**
Location	Sher-e-Bangla Agricultural University soil research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

Table 2. Physical and chemical characteristics of initial soil

Characteristics	Value
% Sand	26
% Silt	45
% Clay	29
Textural class	Silty clay loam
pH	5.8
% Organic carbon	0.6
% Organic matter	1.03
% Total nitrogen	0.03
Available P (ppm)	28
Available S (ppm)	18

3.2.4. 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). The climate of the experimental site is subtropical that is characterized by high temperature and heavy rainfall during Kharif season (April - September) and low rainfall during Rabi season (October – March) associated with moderately low temperature. The experiment was conducted in the month of December 2020 to March 2021 (Robi season). The monthly average minimum and maximum temperature during the crop period was 13^0 to 31.6^0c. The monthly average minimum and maximum relative humidity during the experiment was 41% to 60% and, monthly average minimum and maximum rainfall was 3 mm and 9 mm. 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, Dhaka and has been presented in Appendix- II.

3.3. Experimental details

3.3.1. Plant materials

In this study Indian spinach (*Basella alba L.*), variety- BARI puishak-1 was used as plant material. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Dhaka.

3.3.2. Organic materials

3.3.2.1 Cowdung

Fresh cowdung was collected from Sher-e-Bangla Agricultural University (SAU) farm. Then it was kept for drying and after complete decomposition and drying cowdung was used with Shrimp shell powder.

3.3.2.2 Shrimp shell powder

Shrimp shell powder (Chitosan raw material) was collected from Khulna region of Bangladesh. Then the powder was sieved through 30 mesh sieves to prepare usable form of shrimp shell powder for the experiment.

The composition of Shrimp Shell Powder (SSP) is given below-

Table 3: Composition of the raw shrimp shell powder which was used in the research work.

Name of the nutrients	Nutrient content
Nitrogen (N)	12.61 %
Phosphorus (P)	0.67 %
Potassium (K)	0.28 %
Sulphur (S)	0.1 %
Calcium (Ca)	2.43 %
Magnesium (Mg)	0.36 %
Zinc (Zn)	92.03 ppm
Boron(B)	152 ppm
Organic Carbon (OC)	17.0 %
Organic Matter (OM)	29.31 %

3.3.2.3 Preparation of decomposed shrimp shell powder

Seived Shrimp shell powder was mixed with the decomposed cowdung in a definite ratio for decomposition. The mixed materials were then kept for decomposition for some days. After full decomposition the mixed materials were stirred and then organic material was ready to use. The chemical composition of the prepared organic material was tested and the results are presented in Appendix-III.

3.3.3 Experimental treatments

The single factor experiment was compared with eight different concentration of decomposed shrimp shell powder.

Treatments are as follows:

T_1= 0% of decomposed shrimp shell powder

T_2 = 0.10% of decomposed shrimp shell powder

T_3 = 0.50% of decomposed shrimp shell powder

T_4 = 1% of decomposed shrimp shell powder

T_5 = 2% of decomposed shrimp shell powder

T_6 = 3% of decomposed shrimp shell powder

T_7 = 4% of decomposed shrimp shell powder

T_8 = 5% of decomposed shrimp shell powder

These eight treatments of decomposed shrimp shell powder were applied during potting media preparation.

3.4 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with single factor consist of eight treatments. Each treatment was replicated four times. As, it was a pot experiment, total 32 unit pots was prepared for the experiment with 8 treatments. Each pot was of required size (14 inch).

3.5 Seed collection

Seed of Indian spinach cv. BARI puishak-1 was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.6 Pot preparation

14 inch plastic pot having 26 cm diameter were used for this study. Ten (10) kg soil media was used in per pot. Field moist soil was collected from the farm of Sher-e-Bangla Agricultural University (SAU) then mixed with dry cowdung at 4:1 ratio. Then the mixed soil preparation was mixed with at 0%, 0.10%, 0.50%, 1%, 2%, 3%, 4% and 5% of decomposed shrimp shell powder (chitosan raw material) in soil according to per treatment requirement. No synthetic fertilizer was used. Then the pot was filled with the prepared treated soil. After that seeds were sown in the pot for raising plants.

3.7 Raising of Indian spinach

The experiment was done with 32 plastic pot in total (1 pot for each replication, each treatment comprised of 4 replication or 4 pots). Plastic pot consist of soil preparation that is mentioned in the article 3.6. On 25 December, 2020, BARI puishak-1 seeds were sown on the prepared pot soil.

3.8 Intercultural operations

3.8.1 Fertilizer dose and methods of application

No chemical fertilizer was used in this experiment. Only decomposed shrimp shell powder was used as per treatment during the preparation of potting media

3.8.2 Weeding

Indian spinach plants were infested by some weeds at early stage of plant establishment. Hand weeding was done when required.

3.8.3 Application of irrigation water

Irrigation water was supplied when required to ensure the sufficient moisture for normal growth of Indian spinach. All the pots were watered evenly.

3.8.4 Plant protection measures

No artificial plant protecting measures were taken, no pesticide application was done on plants during the experiment.

3.9 General observation of the experimental field

The field was investigated time to time to detect any visual difference among the treatments and any kind of infestation by weeds, insect and diseases. So that, considerable losses by insect or test could be minimized. Soil moisture condition was monitored on regular basis to avoid any water stress. The field looked nice with normal green colour plants over all. Incidence of Cercospora leaf spot was observed in the later stage of plant growth, but the infestation was below economic threshold level.

3.10 Harvesting

Harvesting was done at 16 March, 2021, after 81 days of sowing. All the vines of Indian spinach was harvested at a time.

3.11 Data collection

The data were recorded at various characterization which is given below-

3.11.1 Morphological parameters of plant

3.11.1.1 Germination percentage

The number of germinated seed of all experimental pot was recorded after 14 days of sowing. Then the number was expressed as percentage.

3.11.1.2 No. of plant pot^{-1}

No. of plants per pot was counted manually after 1 month of sowing and at the time of harvesting.

3.11.1.3 Average plant height (cm)

Plant height (vine length of Indian spinach) was measured with a meter scale from the ground level to tip of the main vine before harvesting. The mean heights were expressed in cm.

3.11.1.4 Average fresh weight (g pot^{-1})

Fresh weight of all plants (vines- edible portion of Indian spinach) were collected after harvesting from each pot and then weighted by using a digital electric balance. The mean weight were expressed in gram.

3.11.1.5 Average oven dry weight (g pot^{-1})

The harvested plants of each pot was kept for sun drying. Then the sun dried vines again dried in oven and weighted by using a digital electric balance & their mean was expressed in gram.

3.11.1.6 Yield increase over control

Yield increase over control was calculated by using the folling formula-

Yield increase over control (%) = $\frac{\text{Treatment yield} - \text{Control yield}}{\text{Control yield}} \times 100\%$

3.12 Chemical analysis of soil samples

Soil samples were collected from each pot soil after harvesting Indian spinach. Various chemical properties of soil sample were analyzed in the laboratory of Department of Soil Science of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207.

The soil was analyzed by following standard methods.

3.12.1 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).

3.12.2 Organic Carbon

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. The mass in the flask was diluted with about 150-200 mL of distill water by mixing conc. H_3PO_4 and 2 mL of diphenylamine indicator. Organic Carbon was calculated by the following formula-

Organic carbon (%) = $\frac{(B-T) \times N}{W} \times 100\%$

Where, B = Blank titration (ml) value, T = Sample titration (ml) value , N = Normality, W = weight of soil

3.12.3 Organic matter

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.

Organic matter (%) = % Organic carbon × 1.73

3.12.4 Total nitrogen

Total N content of soil were determined by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 2000C and added 3 ml H_2O_2 and then heating at 3600C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination. Then 20 ml digest solution was transferred into the distillation flask, then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally, the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% \text{ N} = \frac{(\text{T}-\text{B})\times \text{N} \times 0.014 \times \text{D}}{\text{W}} \times 100\%$$

Where, T = Sample titration (ml) value of standard H_2SO_4, B = Blank titration (ml) value of standard H_2SO_4, N = Strength of H_2SO_4, D = Dilution factor and W = Sample weight in gram.

3.12.5 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, at 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.

3.12.6 Available Sulphur

Available sulphur in soil was determined by calcium chloride extraction method. Available S was extracted from the soil with $CaCl_2$ solution. The available S as the sulphate form may be determined by the turbidity of suspended barium sulphate and hence this is known as turbidimetric method. The turbidity of suspended $BaSO_4$ is produced by treating the soil extract with $BaCl_2 .2H_2O$ crystals. The intensity of the turbidity was then measured by a spectrophotometer at 420nm wavelengths. The procedure by which barium sulphate is precipitated must be carefully controlled as the properties of suspension are influenced by the velocity of reaction. The $BaCl_2$ was added to the sulphate solution in the solid state as crystals of definite size (20-26 mesh) and not as solution. Readings of the turbidity were calibrated with the standard S curve.

3.13 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 with the help of a computer package program name statistix 10.

CHAPTER IV

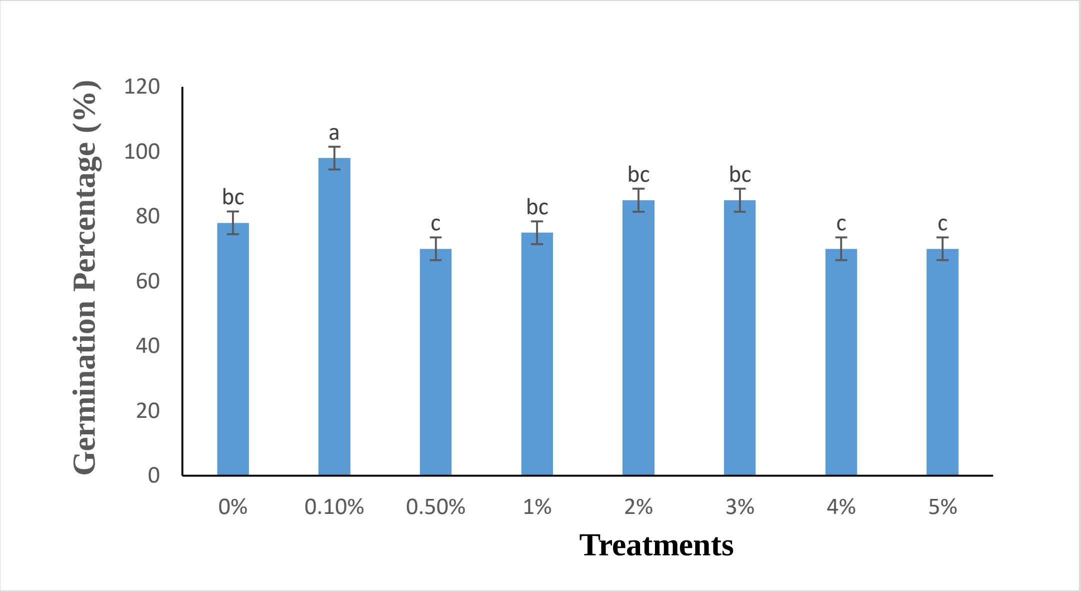
RESULT AND DISCUSSION

Results obtained from the present study have been presented and discussed in this chapter with a view to study the effect of decomposed shrimp shell powder (SSP) on the growth and development of Indian Spinach and soil characteristics. 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 Effect of decomposed shrimp shell powder on plant morphological characteristics and yield attributes of Indian spinach

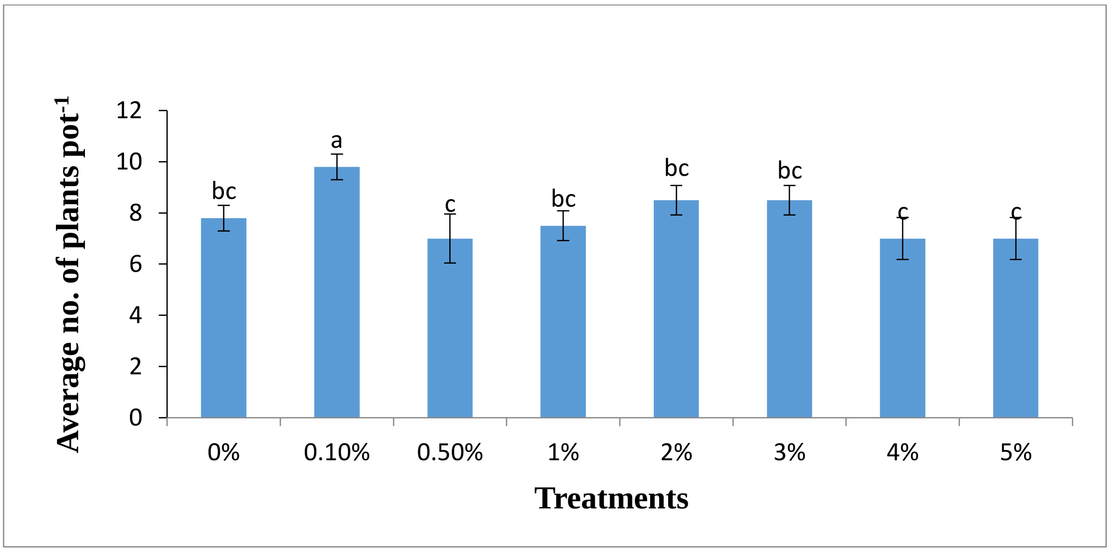
4.1.1 Effect of decomposed SSP on germination percentage and average number of plants/pot per treatment of Indian spinach

Effect of decomposed SSP on germination percentage and average number of plants pot^{-1} were examined. Highest germination percentage was found in T_2 (98%) having 0.1% compost and lowest germination percentage was found in T_3, T_7 and T_8. Except T_2 treatment all other treatments were found to be statistically similar in case of germination percentage (Fig.1). Low concentration of decomposed SSP had positive effect on germination of Indian spinach. It might be the effect of germination enhancing hormone, because this material contain some growth promoting hormone. But in higher concentration it may shows some toxic effect, for that reason germination declined when higher amount of decomposed SSP used. For this factor, we have to find out the plant physiological relation with SSP. Total number of plants of the treatments except T_2 were similar with the control treatment, T_1. The control treatment had 31 plants. Except the T_2 (39), T_5 (32), T_6 (32) all other treatments (T_3, T_4, T_7, T_8) had less than 31 plants. Highest average number of plants/pot was found in T_2 (9.8). All other treatments had statistically similar effect on average number of plants/pot to control treatment, T_1 (Fig.2). So, it confirmed that the material had no effect on germination upto the 5% (w/w).



Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 1: Effect of decomposed SSP on germination percentage of Indian Spinach

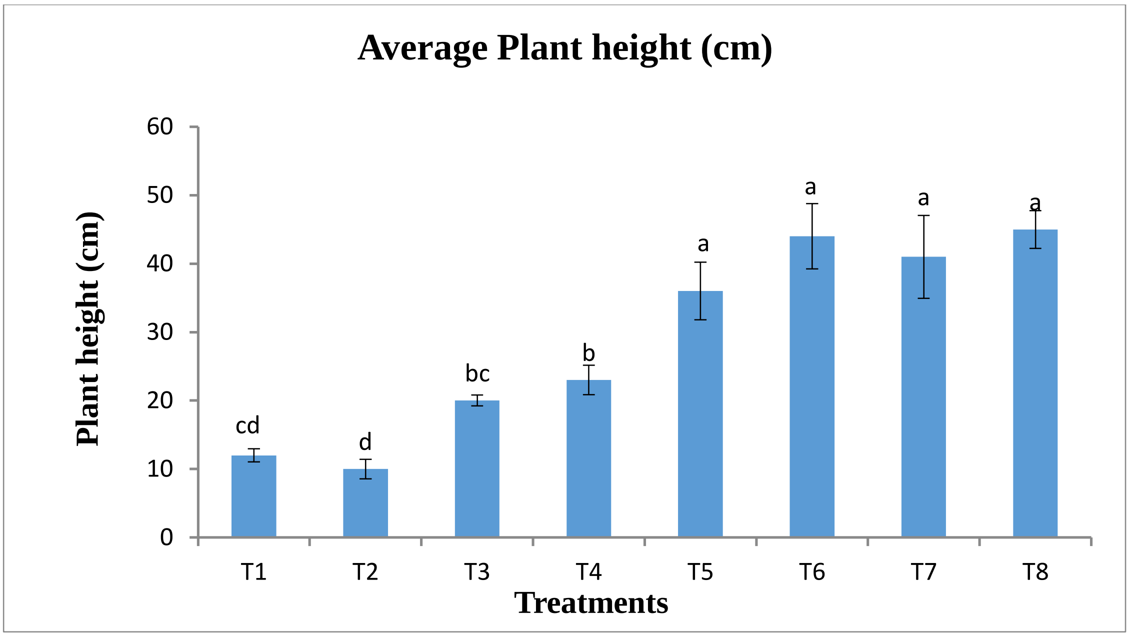


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 2: Effect of decomposed SSP on average no. of plants pot^{-1} of BARI puishak-1. Bar's having similar letter(s) do not differ significantly at $p \leq 0.05$.

4.1.2 Effect of decomposed SSP on the plant height of Indian spinach under Rabi season

Effect of decomposed SSP on plant height of Indian spinach was examined and found that plant height of Indian spinach significantly increased with the treatments. Maximum plant height (45 cm) was found in the T_8 having 5% of decomposed SSP in pot soil. And it was statistically similar with the treatments T_5, T_6 and T_7. The lowest plant height (12 cm) was found in the control treatment, T_1 (Fig.3). Three to four times higher plant height was found in the T_5-T_8 treatments indicating that the plant response to the organic material (SSP) might have a good level of plant nutrients and Plant growth regulators (PGR). This result was supported by Mondol *et al.,* (2011) in Indian spinach, Abirami *et al.,* (2021) in ladies finger (*Abelmoschus esculents L.*) and Martinez *et al.,* (2007) in tomato. Mondol *et al.,* (2011) reported that the highest plant height and leaf number plant^{-1} were obtained in 100 ppm followed by 75 ppm Chitosan application in Indian spinach. Similar result was also found by Chibu *et al.,* (2000) in rice who reported that plant height increased in chitosan applied plants as compared to control plants. Parvin et al., (2019) revealed that plant height was greater in chitosan applied tomato plants than control plants. The longest plant (74 cm) was obtained in T_4 treatment followed by T_9 and T_{10} at 80 DAT whereas shortest plant (62.75 cm) was obtained in control treatment at 80 DAT. Similar result also reported by Metwaly *et al.,* (2023) in strawberry. They reported that, Foliar spraying of CHI and MCT-P considerably improved strawberry plant growth (i.e. plant height, leaf number and area per plant, and foliage fresh weight). Mondol *et al.,* (2016) reported that foliar application of chitosan at early growth stages increased plant height of summer tomato *(L. esculentum).*

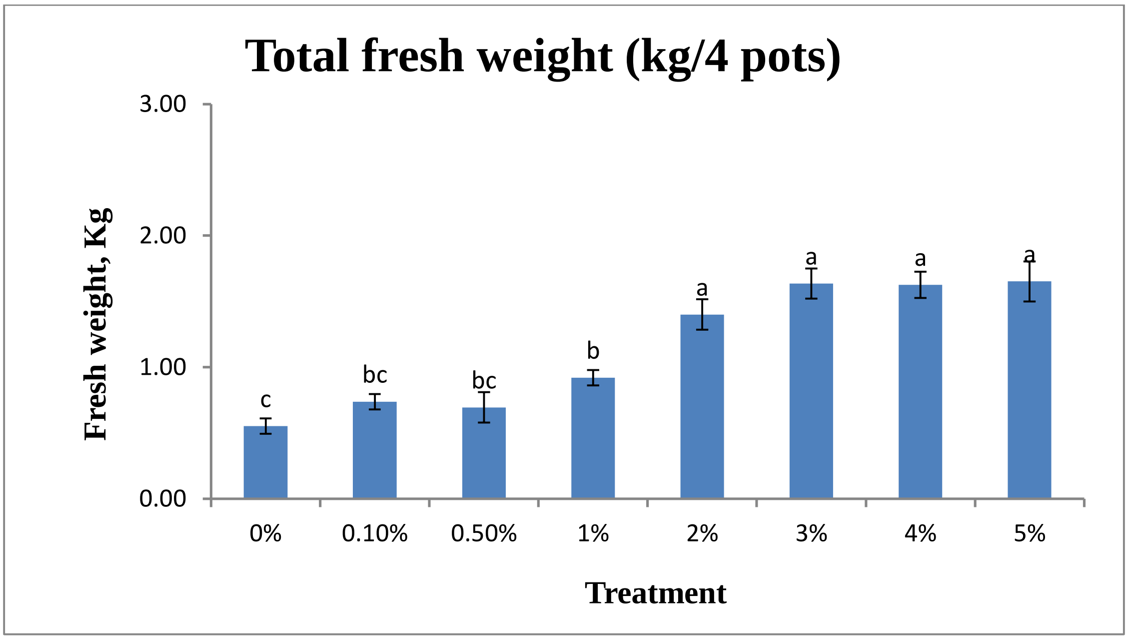


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 3: Effect of decomposed SSP on plant height of Indian spinach. Bar's having similar letter(s) do not differ significantly at $p \leq 0.05$.

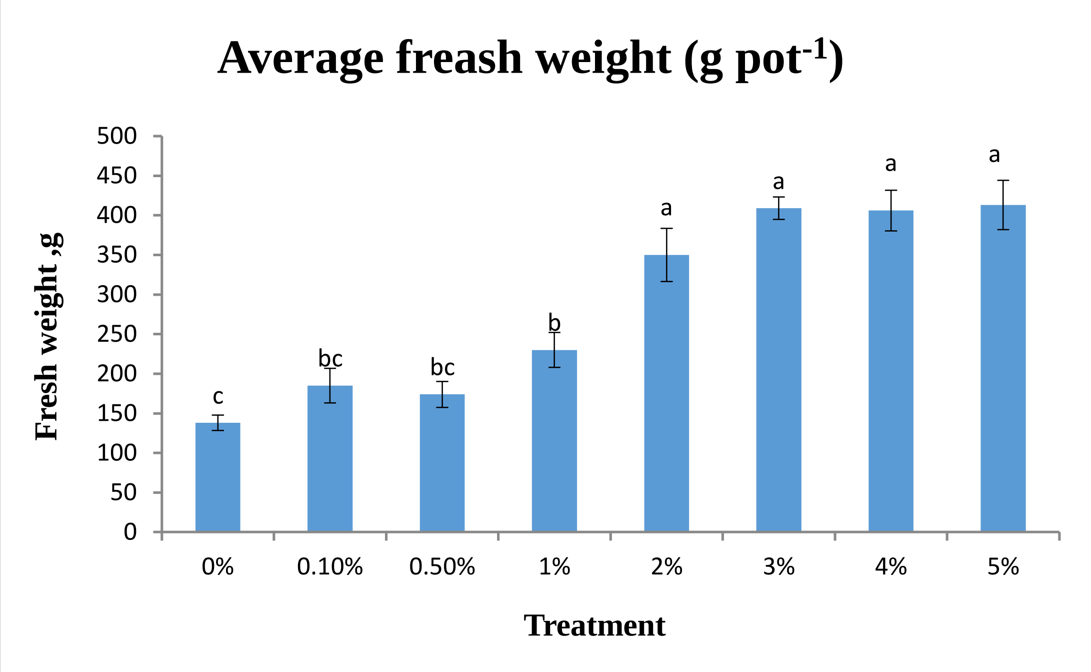
4.1.3 Effect of decomposed SSP on the fresh weight production of Indian spinach under Rabi season

Effect of decomposed shrimp shell powder on fresh weight production of Indian spinach was examined and found that fresh weight of Indian spinach significantly increased with the treatments. All the treatments produce higher fresh weight than the control treatment, T_1 (Fig.4). The fresh weight production increased in a dose dependent manner. Around three to four times higher fresh weight production was found in the T_6-T_8 treatments. So, results showed that this organic material (SSP) had a significant role in fresh weight production of leafy vegetable organically. Decomposed shrimp shell powder could be a good source of essential plant nutrients. The total fresh weight production per treatment was higher in treatment T_8 (1650g) which was statistically identical with T_5, T_6 and T_7 (Fig.4). Though the number of plants was higher in control treatment T_1 (31 plants) than treatment T_8 (Fig.2), T_8 showed the highest fresh weight production (Fig.5). Average fresh weight production per treatment was also higher in treatment T_8 (413g), where control treatment T_1 has average fresh weight production of only 138g. The average fresh weight production of treatment T_5, T_6, T_7 was statistically similar with treatment T8. The result of treatment T_1 was statistically similar with T_2 &T_3. This result was supported by Mondol *et al.*, (2011) in Indian spinach. They reported that branch number, leaf area, leaf and stem fresh weight as well as total fresh weight increased till 75 ppm followed by a decline with higher concentration. Xu *et al.*, (2018) also reported that Chitosan at 0.05%, 0.10%, and 0.15% increased leaf area from 674 to 856, 847, and 856 cm 2, and leaf fresh weight from 28.6 to 39.4, 39.1, and 39.8 g, respectively in lettuce. El-Tanahy *et al*.,(2012) also reported that best effect on plant vegetative growth (plant height, number, fresh and dry weights of leaves and shoots), yield and its component (pod length, weight and diameter and number. of seeds and seed yield) was obtained by using the highest concentration of Chitosan (5%) with the application of the inorganic fertilizer in cowpea. Similar results also found in ladies finger by Abirami *et al.*, (2021). They found that SSP compost can increase plant height, fruit production and fruit weight of okra.



Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 4: Effect of decomposed SSP on total fresh weight production of Indian spinach. Bar's having similar letter(s) do not differ significantly at $p \leq 0.05$.

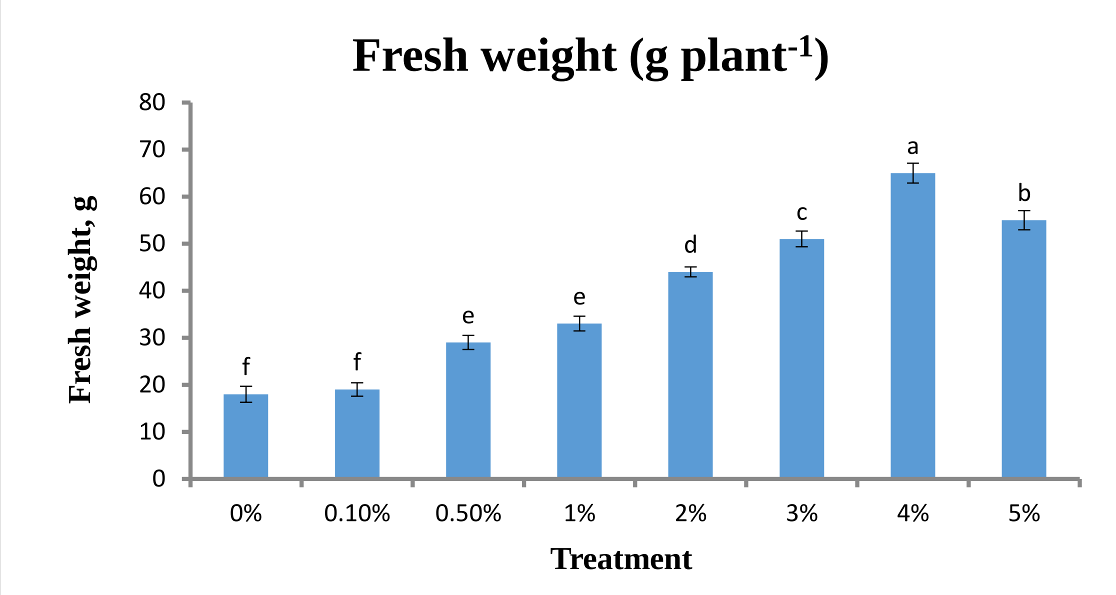


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 5: Effect of decomposed SSP on average fresh weight production of Indian spinach. Bar's having similar letter(s) do not differ significantly at $p \leq 0.05$.

4.1.4 Effect of decomposed SSP on the individual plant fresh weight production of Indian spinach under Rabi season

Fresh weight production by the individual plant was observed higher in all treatments compared to the control. The fresh weight production was approximately 2 to 3 times hand sometimes more than 3 times higher than the control. Highest individual fresh weight (65.5g) production was found in 4% application of decomposed SSP, T_7 treatment and lowest individual fresh weight (18.5g) was found in control treatment T_1 where decomposed shrimp shell powder was not applied (Fig.6). The result indicate that decomposed SSP is a good source of plant nutrients. Similar result was also found by Mondol *et al.*, (2011) in indian spinach, Xu *et al.*, (2018) in lettuce and El-Tanahy *et al.*, (2012) in cowpea.

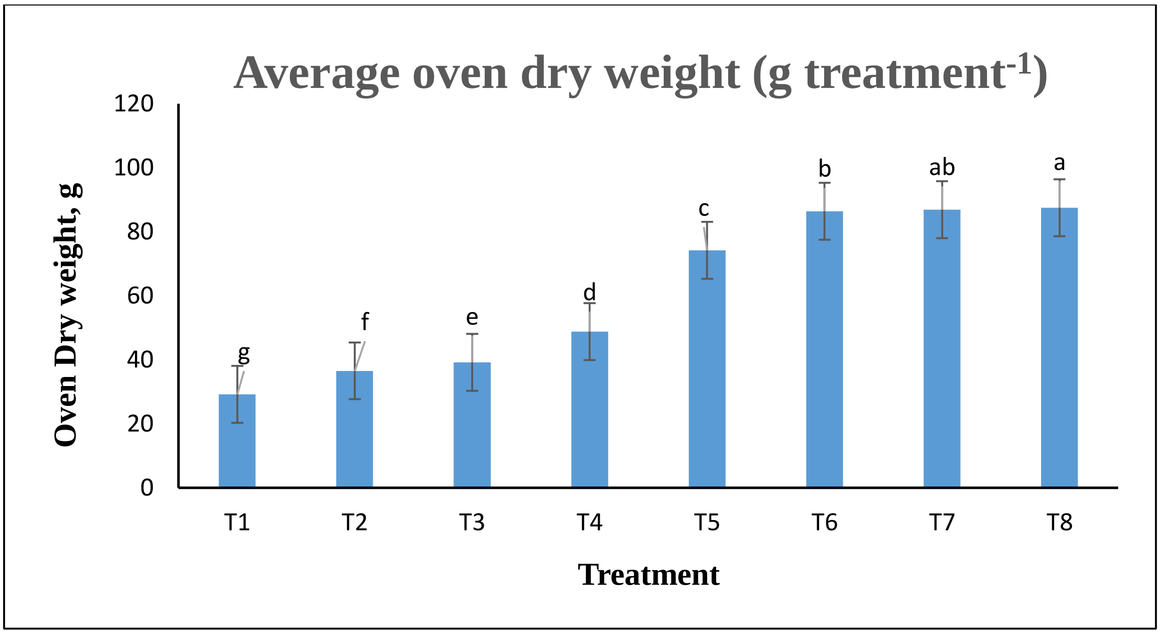


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 6: Effect of decomposed SSP on the individual plant fresh weight production of Indian spinach. Bar's having similar letter(s) do not differ significantly at p≤ 0.05.

4.1.5 Effect of decomposed SSP on the plant dry weight production of Indian spinach under Rabi season

Plant dry weight production was found to increase in a dose dependent manner of different treatment combinations. As Indian spinach contain water and minerals in a large portion of its weight, the dry weight represents the fiber weight actually. Maximum average dry weight of plant (87.6g) was found in T_8 treatment having 5% application of decomposed SSP in soil. The minimum average dry weight (29.25g) was found in control treatment T_1 (Fig.7). All the treatments shows statistically higher dry weight production than control treatment T_1. The second highest oven dry weight production was found in treatment T_7, which showed statistically similar result with treatment T_8. These results indicate that oven dry weight production of BARI puishak-1 were greatly influenced by application of the decomposed shrimp shell powder. This might be due to its nutritional support, growth promoting hormonal activity and improvement of biological as well as physiochemical properties of the pot soil (Tsugita et al., (1993); Rahman (2015); Islam (2016); Issak (2017)).

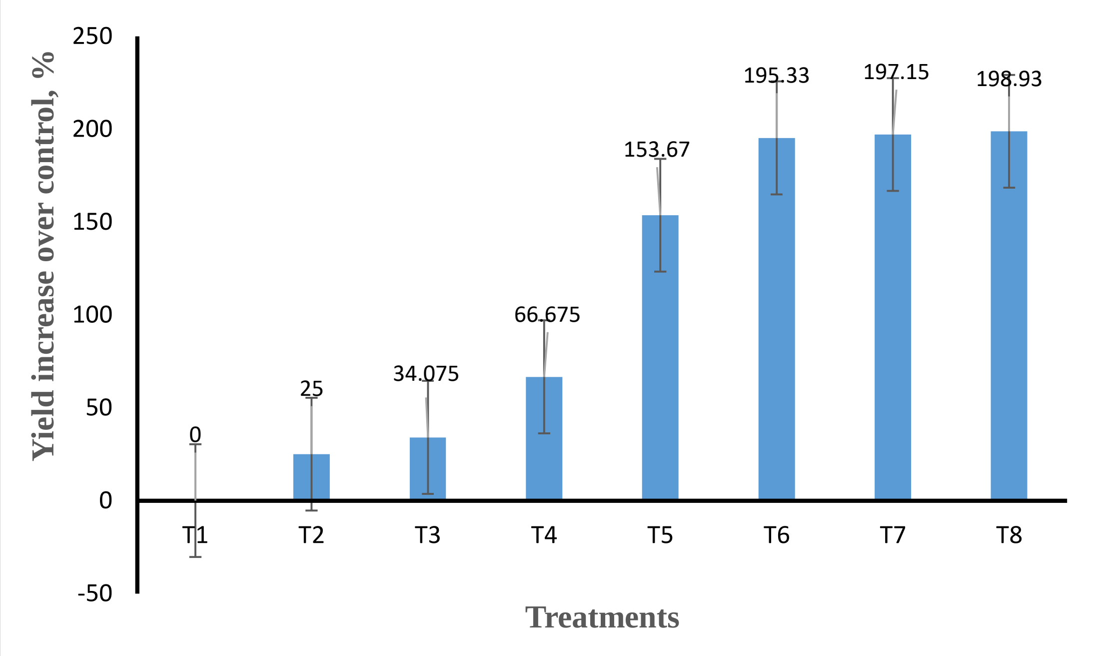


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 7: Effect of decomposed SSP on the individual plant fresh weight production of Indian spinach. Bar's having similar letter(s) do not differ significantly at p≤ 0.05.

4.1.6 Decomposed SSP influenced yield improvement over control

Different doses of decomposed SSP have significant effect on yield increase over control treatment. Each treatment showed tremendous increment in yield over control. However, the edible part of Indian spinach (stem with leaves) production increased 25%, 34.075%, 66.675%, 153.67%, 195.33%, 197.15%, and 198.93% in the treatments from T_2 to T_8 chronologically (Fig.8). Around 2 times more yield was got from treatment T_6-T_8. According to yield increase over control, the treatments may be arranged as $T_8 > T_7 > T_6 > T_5 > T_4 > T_3 > T_2 > T_1$. This result is supported by Rahman (2015), who conducted an experiment on tomato and found that highest 157.14% yield increase had got from T_5 treatment over control. Mondal *et al.*, (2012) found that yield increase in indian spinach by using chitosan. Abirami *et al.*, (2021) also found yield increase in okra by using shrimp shell powder.



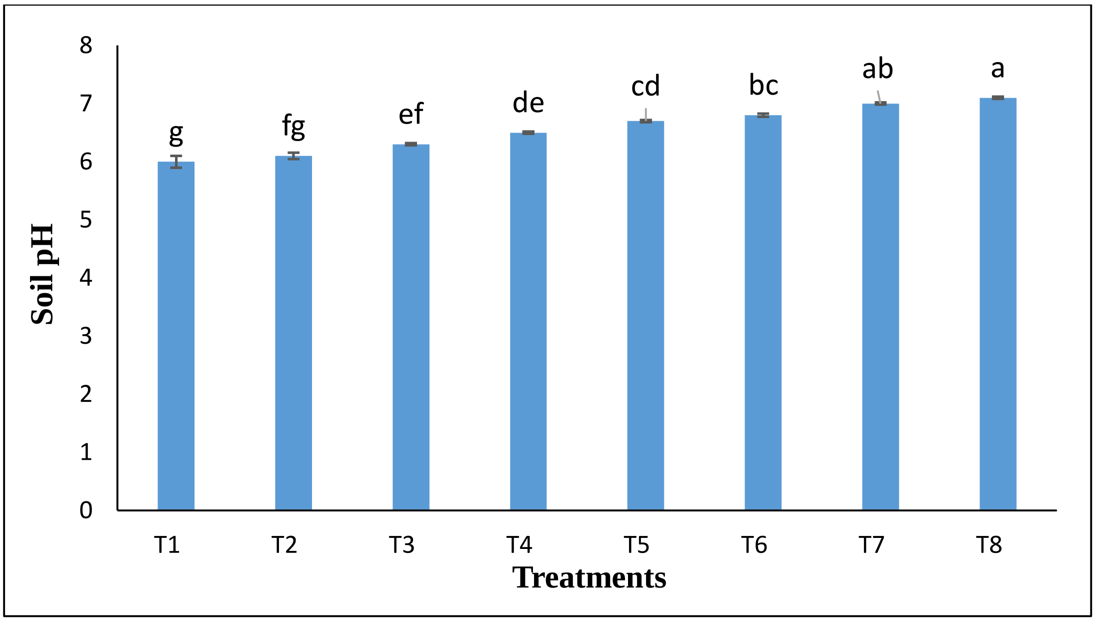
Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 8: Effect of decomposed SSP on the Yield increase over control (%) of Indian spinach. Bar's having similar letter(s) do not differ significantly at $p \leq 0.05$.

4.2 Effect of decomposed SSP on soil chemical properties

4.2.1 Effect on pH status of soil

A significant variation was found in pot soil after harvesting Indian spinach due to the different treatment combination of the decomposed SSP. The pH value of the pot soil was ranged from 6 to 7.1 (Fig.9). The highest pH value was recorded in treatment having 5% of decomposed SSP pot^{-1} soil, T_8. On the other hand, the lowest pH value was recorded in control treatment T_1. According to soil pH, the treatments may be arranged as $T_8 > T_7 > T_6 > T_5 > T_4 > T_3 > T_2 > T_1$. Application of the decomposed SSP might have some neutralizing power, which might have improved the soil environment by the increment of soil pH level. The material SSP itself is a chitin substance and has alkaline nature. The organic material (SSP) amends soil environment by neutralizing soil pH, as nutrient supplementation will be increased due to the increase in pH level. It also improves the soil's biological and physio-chemical properties. This result is supported by Rahman (2015) and Islam (2016), who found that modified chitosan powder increases the soil pH that could be a good point of nutrient mineralization in soil from organic sources. Kananot *et al.*, (2015) conducted an experiment with fermented chitin waste (FCW) along with CF = soil supplemented with chemical fertilizer and CMF = soil supplemented with chicken manure fertilizer. The results reported that FCW @ 1% the pH differ significantly from 0.5%FCW, 0.25% FCW and rest of the treatments. The reason behind the increase of soil pH may be the chitosan raw material (shrimp shell powder). Because the shrimp shell contain most abundant carbonates of Ca & Mg (Beaney *et al.*, 2005; Mahmoud *et al*., 2007; Sultana *et al.*, 2020).

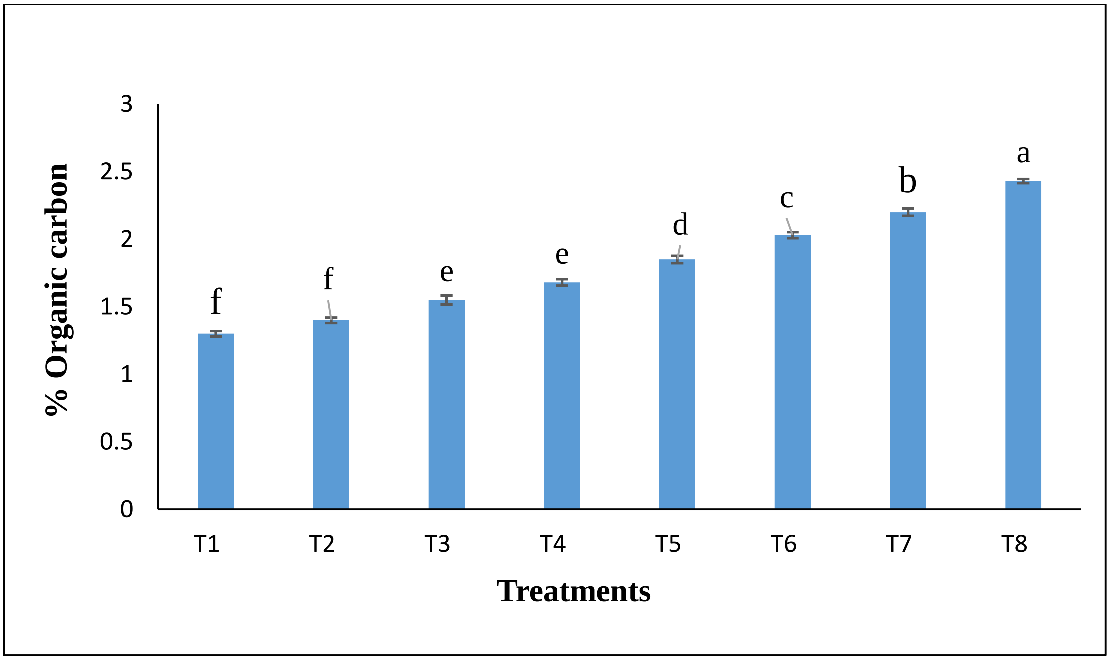


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 9: Effect of decomposed SSP on soil pH. Bar's having similar letter(s) do not differ significantly at p≤ 0.05.

4.2.2 Effect on organic carbon content of soil

Increment of soil organic carbon content were found due to the application o of decomposed SSP in the soil. The organic carbon content was increased with the increasing level of decomposed SSP used in soil (Fig.10). Maximum organic carbon content (2.43%) was found in treatment T_8 having 5% application of decomposed SSP in pot soil, and it is statistically different from any other treatments. Minimum organic carbon content (1.3%) was found in control Treatment T_1 having 0% or no application of the compost. The organic carbon content was increased in a dose dependent manner, it might be due to the use of the organic material which contain cowdung and shrimp shell powder. Shrimp shell powder is enriched with high amount of organic carbon level. The result suggests that application of decomposed SSP might tend to increase the soil organic carbon level and thus it would improve and sustain soil health. Sultana *et al.,* (2020) suggested that residual effect of chitosan raw material powder increase the soil organic carbon content. Kananot *et al.,* (2015) also reported that fermented chitin waste had increased organic matter content in soil in a dose dependent manner. Rahman (2015) and Islam (2016) also found that application of chitosan raw material powder increase organic carbon content in soil. Increasing soil organic matter and carbon for sustainable agriculture is a big challenge in Bangladesh soils; however application of this the organic material (SSP) can play an important role. Besides, it can also ensure a good waste management. Moreover, in case of rooftop gardening this compost can be very useful as it can provide good soil environment.

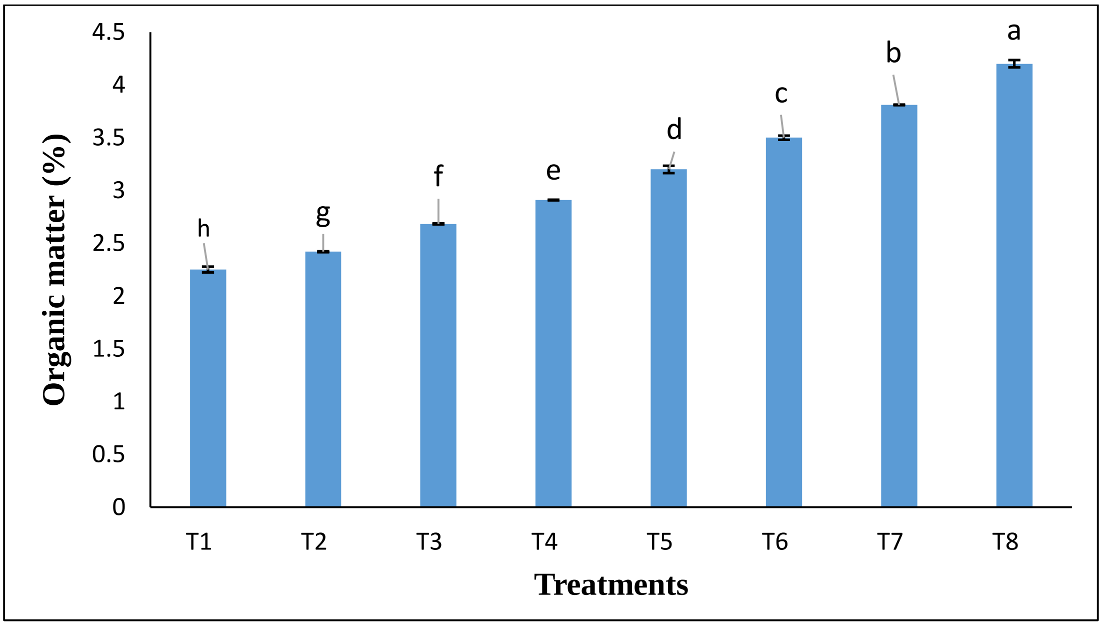


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 10: Effect of decomposed SSP on organic carbon content of soil. Bar's having similar letter(s) do not differ significantly at $p \leq 0.05$.

4.2.3 Effect on organic matter content of soil

Soil organic matter content showed variations among treatment combinations. Organic matter content of pot soil was varied from 2.25% to 4.2% respectively among the treatments (Fig.11). Maximum organic matter content 4.2% was found in treatment T_8 which had 5% application of decomposed shrimp shell powder in soil. Whereas lowest organic matter content was found in treatment T_1 which have 0% application of the decomposed SSP but have cowdung in soil. According to the organic matter content of soil, the treatments maybe arranged as $T_8>T_7>T_6>T_5>T_4>T_3>T_2>T_1$. Organic matter content in Bangladeshi soil is normally low. For maintaining soil health and sustainable agriculture organic matter is a big concern. In this matter, this material can play a significant role. In rooftop gardening or homestead gardening this material can used as organic source of nutrients. This result is supported by Kananot *et al.*, (2015), they reported that fermented chitin waste had increased organic matter content in soil. Sultana *et al.*, (2020) revealed that residual effect of chitosan raw material powder increase the soil organic carbon content as well as organic matter content. Rahman (2015) and Islam (2016) also reported similar observations.

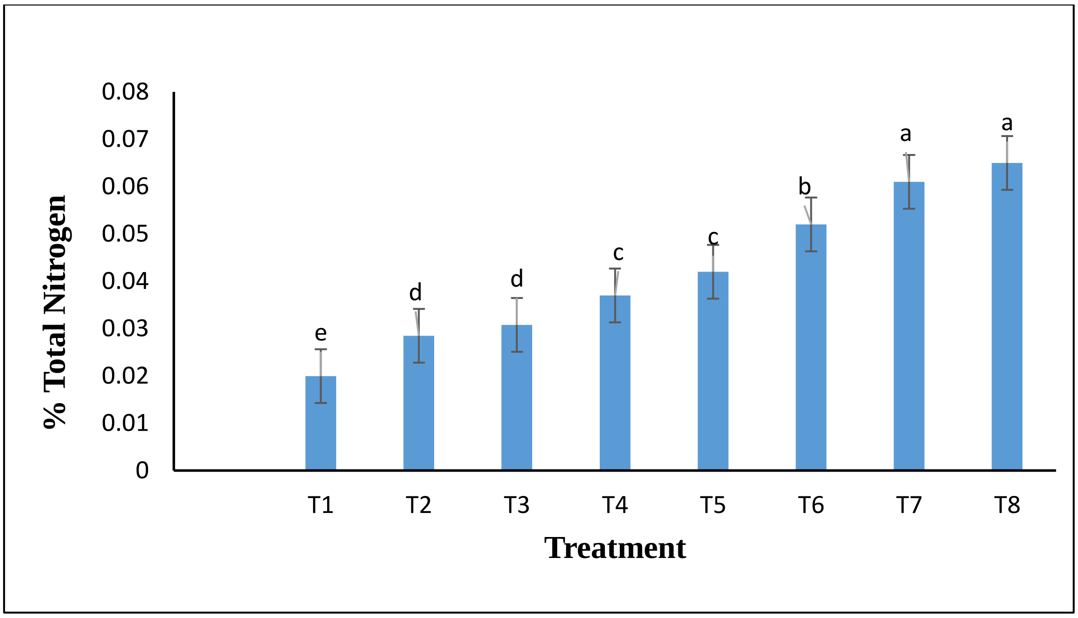


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 11: Effect of decomposed SSP on organic matter content of soil. Bar's having similar letter(s) do not differ significantly at p≤ 0.05.

4.2.4 Effect on total Nitrogen content of soil

A significant variation in nitrogen content was found in pot soil after harvesting indian spinach due to the different treatment combination of decomposed SSP. Total N status of soil after harvesting was ranged from 0.02% to 0.65% (Fig. 12). Results showed that N status of soil was statistically different among the treatments. The highest N status (0.65%) was found in the treatment T_8 and lowest value (.02%) was recorded in the treatment T_1 which is control condition. Value of T_8 was statistically similar with T_7 having 4% of the decomposed SSP application in soil. Treatment T_5 and T_4 were statistically similar with each other and treatment T_3 &T_2 were found statistically similar nitrogen content. This result indicated that total nitrogen content was increased in dose dependent manner of treatment combination. The decomposed SSP can play a significant role in N supplementation, as shrimp shell contain chitin- protein (protein contain nitrogen as amine), that's why it can supply nitrogen in soil. As no inorganic fertilizers were applied the plants got nitrogen only from the organic source (SSP). For this reason, after harvesting the soil nitrogen status is poor. Because plant consume a higher amount of nitrogen for growth and development. In treatment $T_{1,}$ plants get some nitrogen from cowdung and existing nitrogen content of initial soil. Similar results were found by Sultana *et al.,* (2020). She conducted an experiment with chitosan raw material powder and the results revealed that the total nitrogen content in the post-harvest soils were increased due to the residual effect of the CHT powder in rice growing soils. Abirami *et al.,* (2021) also found that nitrogen, phosphorus and potash content were increased in the shrimp shell composts (SSC) with adding chitinase producing bacterium (*Bacillus licheniformis* SSCL10) when compared with control soil.

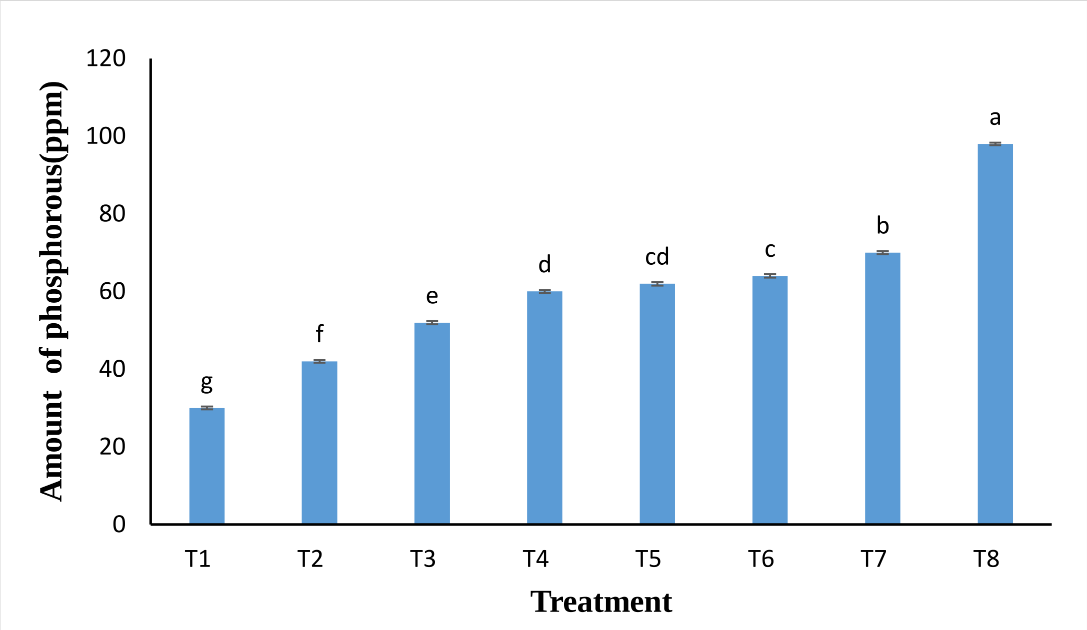


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 12: Effect of decomposed SSP on total nitrogen (%) content of soil. Bar's having similar letter(s) do not differ significantly at $p \leq 0.05$.

4.2.5 Effect on available phosphorous content of soil

Application of decomposed SSP influenced soil available phosphorous content significantly. The maximum available phosphorous content 98 ppm was found in the treatment T_8 having 5% application of decomposed SSP. Whereas, the minimum available phosphorus content 30 ppm was found in the control treatment T_1 (Fig.13). All the treatments showed higher amount of phosphorous content than T_1 treatment. The treatment T_8 showed highest and it is significantly differ from others. Treatment T_5 had statistically similar phosphorous content with treatment T_6 and T_4. This happened due to the application of decomposed SSP. This result indicated that available phosphorous content had increased with the application of treatment combination. This result is supported by Abirami *et al.*, (2021), they found that nitrogen, phosphorus and potash content were increased in the shrimp shell composts (SSC) with adding chitinase producing bacterium (*Bacillus licheniformis* SSCL10) when compared with control soil.

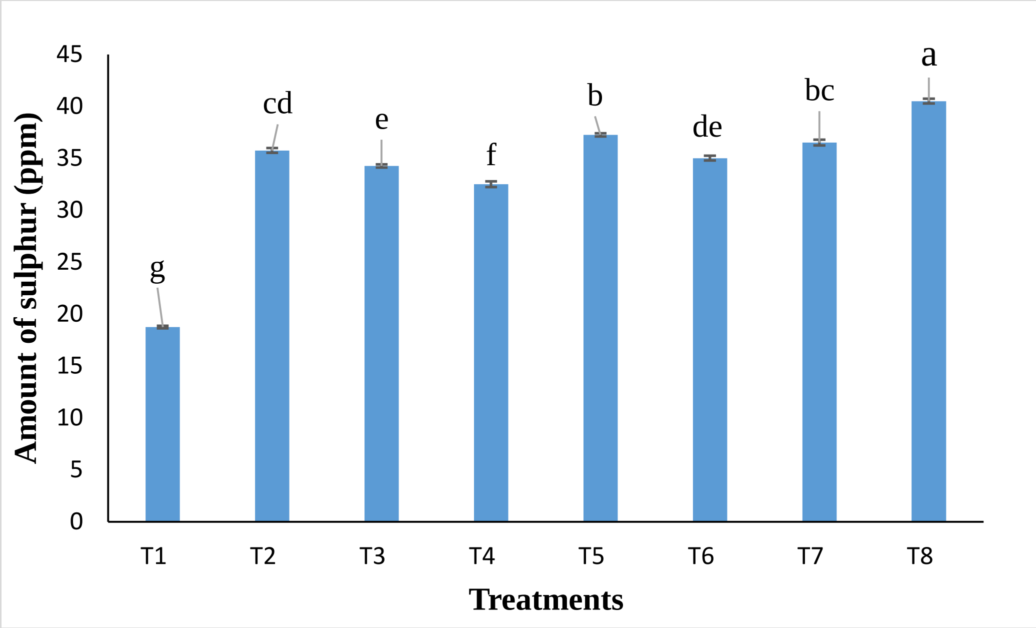


Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 13: Effect of decomposed SSP on available phosphorous content of soil. Bar's having similar letter(s) do not differ significantly at $p \leq 0.05$.

4.2.6 Effect on available sulphur content of soil

Sulphur content of soil was also improved by the application of decomposed SSP. Though it is very difficult to supply sulphur from organic sources in full fledge this compost showed an increment in sulphur content in soil. The highest sulphur content in soil was found in which 5% of decomposed SSP was applied that is treatment T_8. The result did not show a uniform increase but all the treated soil had higher sulphur content than control treatment T_1 (Fig. 14). All the soil treated with organic material (SSP) have sulphur in a range of 35-40 ppm, whereas, control treatment T_1 had only 18.75ppm sulphur. Treatment T_5 is statistically similar with treatment T_7. Treatment T_7 also statistically similar to treatment T_2. Treatment T_2 was found statistically similar results with treatment T_6 and T_6 also statistically similar to treatment T_3. In organic cultivation, sulphur is supplemented by synthetic fertilizer. But in this case we can get sulphur from the decomposed SSP at certain extent.



Different percentage of decomposed SSP were used in the treatments as follows: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5%.

Figure 14: Effect of decomposed SSP on available sulphur content of soil. Bar's having similar letter(s) do not differ significantly at p≤ 0.05.

CHAPTER V

SUMMARY AND CONCLUSSION

A pot experiment was conducted under the net house of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, during the period from December 2020 to march 2021 to investigate the growth and yield of Indian spinach by using of decomposed shrimp shell powder and also soil nutrient content after harvesting the crop under the Madhupur Tract (AEZ-28). The experiment was comprised of eight level of decomposed SSP made by using shrimp shell powder and the treatments were: T_1=0%, T_2=0.1%, T_3=0.5%, T_4=1%, T_5=2%, T_6=3%, T_7=4%, T_8=5% application of decomposed SSP.

The single factor experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications.

Application of decomposed SSP had a profound influence on plant height, fresh weight and yield attributes in Indian spinach. The decomposed shrimp shell powder enhanced the soil characteristics in such a way that induced the plant growth and boosts up the yield. All the traits were significantly increase with the increase of application o of decomposed SSP. The use of organic material (SSP) not only gave higher growth and yield but also improves the soil properties viz. soil organic matter, phosphorous, nitrogen content etc. that helped to maintains soil health and keeps the soil and environment free from pollution.

The application of decomposed SSP had no negative effect on germination of plants upto 5% (w/w). At low concentration it can enhance the germination percentage.

The application of decomposed SSP had a significant influence on plant height of Indian spinach. Maximum plant height (45 cm) was found in the treatment T_8 having 5% of decomposed SSP in pot soil which was statistically similar with the treatments T_5, T_6 and T_7 treatments. The lowest plant height (12 cm) was found in the control treatment, T_1 which was significantly different from all other treatments. Around three to four times higher plant height was found in the T_5-T_8 treatments than control.

Plant fresh weight of Indian spinach was greatly influenced by the application of decomposed SSP. Fresh weight of Indian spinach significantly increased with the treatments. The fresh weight production increased in a dose dependent manner. Around three to four times higher fresh weight production was found in the T_6-T_8 treatments. Maximum total fresh weight production about 1.65 kg was got from T_8 treatment which contain 5% of decomposed SSP in soil. Whereas only 0.55 kg total fresh weight production was found in control treatment T_1 which is lowest in terms of all treatments. Treatment T_5, T_6, T_7 had statistically similar production of total fresh weight with treatment T_8. In spite of having less number of plants than control treatment T_1 (31 plants), treatment T_8, T_8 showed the highest average fresh weight production. Average fresh weight production per treatment was also higher in treatment T_8 (413g) which was statistically similar with T_5, T_6 & T_7. Whereas, control treatment T_1 has average fresh weight production of only 138g. The average fresh weight production of treatment T_5, T_6, T_7 was statistically similar with treatment T_8.

Fresh weight production by the individual plant was also found higher in all treatments compared to control. Highest individual fresh weight production 65.5g was found in 4% application of decomposed SSP in T_7 treatment and lowest 18.5g in control treatment T_1 where decomposed SSP was not applied.

Plant dry weight production was found to increase in a dose dependent manner of different treatment combinations. Maximum average dry weight 87.6g was found in T_8 treatment having 5% application of decomposed SSP in soil. The minimum average dry weight 29.25g was found in control treatment T_1. All the treatments shows statistically higher dry weight production than control treatment T_1. The second highest oven dry weight production was found in treatment $T_{7,}$ which showed statistically similar result with treatment T_8.

In case of soil chemical properties, the soil was neutralized by the application of decomposed SSP. Soil pH value of the pot soil was ranged from 6 to 7.1. The highest pH value was recorded in treatment T_8 (5% of decomposed SSP /pot soil). On the other hand, the lowest pH value was recorded in control treatment T_1 (5% of decomposed SSP / pot soil).

It was revealed that organic carbon content was increased with the increasing level of decomposed SSP used in soil. Maximum organic carbon content 2.43% was found in treatment T_8 (5% application of decomposed SSP in pot soil) and it is statistically different from any other treatments. Minimum organic carbon content 1.3% was found in control Treatment T_1 (0% or no application of the decomposed SSP). Maximum organic matter content 4.2% was found in treatment T_8 which had 5% application of decomposed SSP in soil. Whereas lowest organic matter content 2.25% was found in treatment T_1 which had 0% application of decomposed SSP but have cowdung in soil. According to the organic matter content of soil, the treatments maybe arranged as $T_8>T_7>T_6>T_5>T_4>T_3>T_2>T_1$.

The highest soil N content 0.065% was found in T_8 treatment using 5% of the organic material (SSP) in soil and lowest value 0.02% was recorded in T_1 treatment which is control condition. Value of T_8 was statistically similar with T_7 having 4% decomposed SSP application in soil.

Application of decomposed SSP also influenced soil available phosphorous content significantly. The maximum available phosphorous content 98 ppm was found in the treatment T_8 whereas, the minimum available phosphorus content 30 ppm was found in the control treatment T_1. All the treatments showed higher amount of phosphorous content than T_1 treatment. The treatment T_8 showed highest and it is significantly differ from others. Treatment T_5 had statistically similar phosphorous content with treatment T_6 and T_4.

In case of sulphur content, decomposed shrimp shell powder showed an increment though it is very difficult to supply sulphur from organic sources in full fledge. All the treated soil had higher sulphur content than control treatment T_1, but results were not uniform. All the soil treated with decomposed SSP had sulphur in a range of 35-40 ppm. The highest sulphur content 40 ppm in soil was found in T_8 (5% application of decomposed SSP in pot soil), whereas, control treatment T_1 had only 18.75ppm sulphur.

The experiment was conducted to investigate the effect of decomposed SSP on growth and yield attributes of Indian spinach and soil chemical properties under silty clay loam soil. The experiment results indicated that the application of decomposed SSP has increased the growth attributes and fresh weight yield of Indian Spinach cv.BARI puishak-1. Moreover, it also disclosed that a positive increment or improvement was found in soil chemical properties.

Based on the experimental results, it can be concluded that,

i. Application of the decomposed shrimp shell powder in the pot soil had a significant influence on plant morphological growth and yield attributes in Indian spinach cv. BARI puishak-1.
ii. Application of 5% decomposed SSP in soil had the superiority in case of plant height, weight and yield attributes over other treatments 0%, 0.1%, 0.5%, 1%, 2%, 3%, 4% application of decomposed SSP in Indian spinach cultivation.
iii. The decomposed shrimp shell powder had improved the chemical properties of soil. Soil health and environment was improved by the organic material application and it opened a door for sustainable agriculture.

RECOMMENDATION:

From the findings, it is apparent that 5% application of decomposed SSP in soil performed better on plant morphological characteristics that maximize yield of Indian spinach cv. BARI puishak-1. 3% and 4% application of decomposed shrimp shell powder in soil also gives similar yield as 5% application. It also found that 5% application of decomposed SSP in soil performed better for soil nutritional condition and soil health. So, it is suggested that people can use decomposed SSP for Indian spinach cv. BARI puishak-1 cultivation as organic fertilizer.

In order to recommend the practices, the following aspects would be considered in future:

i. Similar experiments need to be conducted in field condition in different locations and seasons of Bangladesh to draw a final conclusion regarding to the effect of the of decomposed SSP on indian spinach cultivation.

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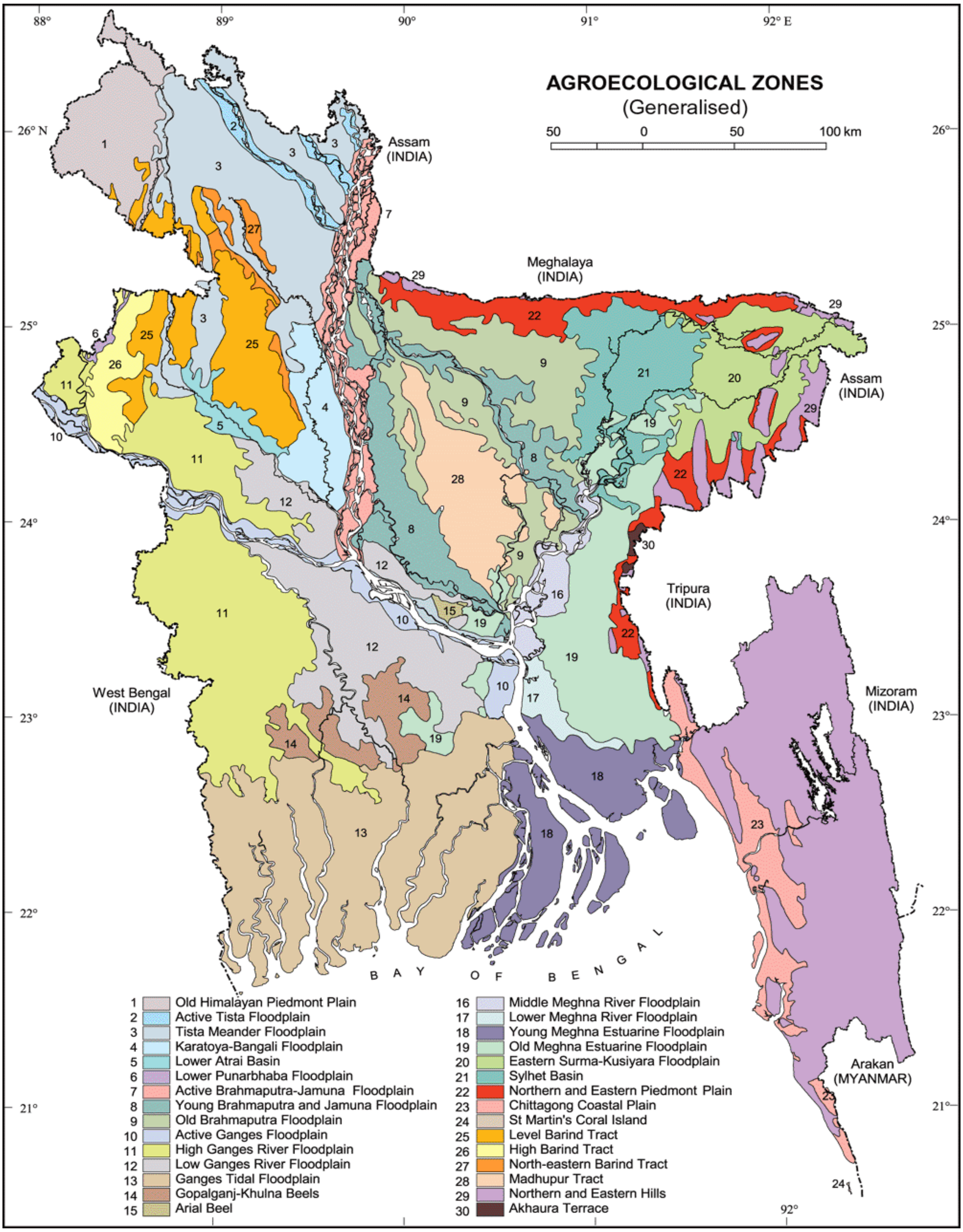
APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Monthly meteorological information during the period from December, 2020 to March 2021

Year	Month	Air temperature (^0C)		Relative humidity (%)	Average Rainfall (mm)
		Maximum	Minimum		
2020	December	27.6	18.7	47%	3 mm
2021	January	25.5	13.1	41%	00 mm
	February	26.7	14	34%	7.5 mm
	March	31.6	20.3	60%	8 mm

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

Appendix III. Composition of decomposed SSP used in the research work

Name of the nutrients	**Nutrient content**
Nitrogen (N)	5-7 %
Phosphorus (P)	0.643 %
Potassium (K)	0.28 %
Sulphur (S)	0.092 %
Organic Carbon (OC)	17%
Organic Matter (OM)	29.3%
pH	8.5

PLATES

Plate 1: Pictorial view of the experimental field

Plate 2: Pictorial view of the plants under different treatments

Plate 3: Pictorial view of the plants after harvesting

Plate 4: Soil pH analysis by pH meter

Plate 5: Pictures during Soil analysis

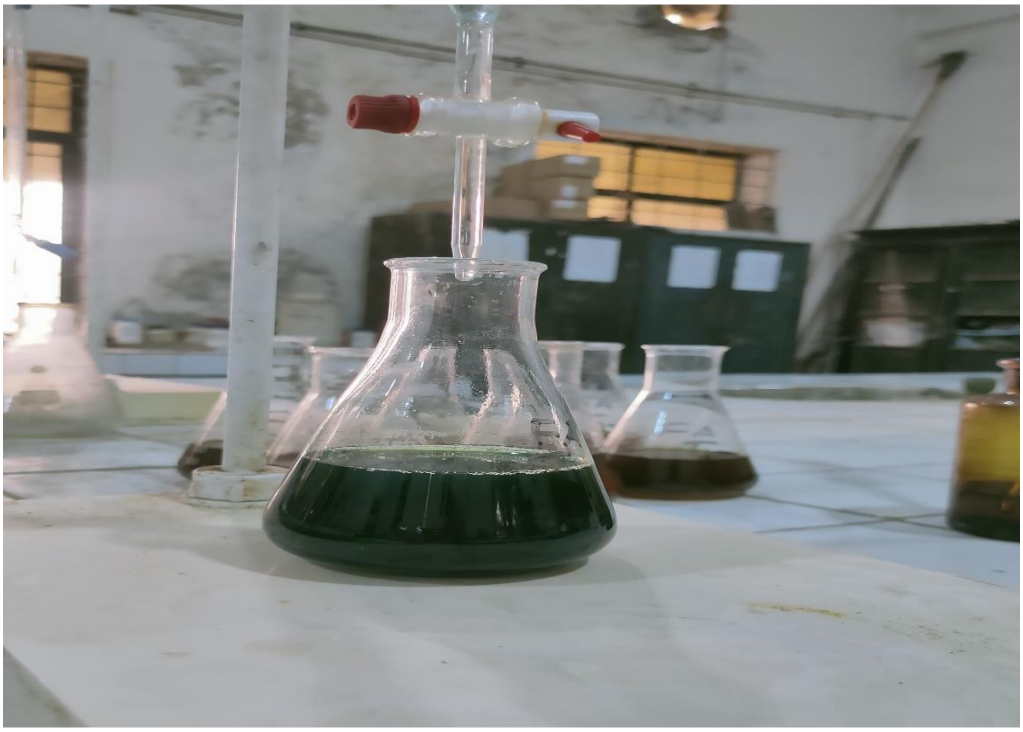


Plate 6: Pictorial view of organic carbon analysis