EFFECT OF MULCH MATERIALS AND FOLIAR APPLICATION OF MICRONUTRIENTS ON THE GROWTH AND YIELD OF SWEET PEPPER UNDER NET HOUSE

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CERTIFICATE

This is to certify that the thesis entitled ***'EFFECT OF MULCH MATERIALS AND FOLIAR APPLICATION OF MICRONUTRIENTS ON THE GROWTH AND YIELD OF SWEET PEPPER UNDER NET HOUSE'*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***HORTICULTURE****, embodies the result of a piece of bona fide research work carried out by* ***MST. SHAPLA AKTER****, Registration No.:* ***19-10379,*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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Dedicated to My Beloved Parents

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The Author

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ABSTRACT

The experiment was carried out at the "Horticulture Farm" of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November 2020 to April 2021 to study the effect of different mulch materials and foliar application of micronutrients on growth and yield of sweet pepper under net house. The experiment consisted of two factors. Factor A: Three mulch materials *viz.*, M_0- No mulch (control), M_2- Black polyethylene mulch and M_2- Rice straw mulch and Factor B: Three foliar application of micronutrients *viz.*, N_0- control (No micronutrients), N_1- Zn @0.6% as $ZnSO_4$ and N_2- B @0.6% as H_3BO_3. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data were recorded on growth, yield components, yield and quality of sweet pepper and significant variation was observed for most of the studied characters. Under this investigation, it was revealed that the highest fruit yield (63.00 t/ha) with net return (Tk. 1,458,860) and benefit cost ratio (BCR) was obtained (4.67) from M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) treatment combination. On the other hand, the lowest fruit yield (24.50 t/ha) with net return (Tk. 377,364) and benefit cost ratio (BCR) was obtained (2.05) from M_0N_0 (control) treatment combination. So, economic analysis revealed that the M_2N_2 treatment combination appeared to be best for achieving the higher growth, fruit yield and economic benefit of sweet pepper.

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LIST OF ACRONYMS

Acronym		Full meanings
AEZ	=	Agro-Ecological Zone
%	=	Percent
^0C	=	Degree Celsius
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
CV%	=	Percentage of coefficient of variance
cv.	=	Cultivar
DAS	=	Days after sowing
DAT	=	Days after transplanting
et al.	=	And others
FAO	=	Food and Agriculture Organization of United States
g	=	Gram
ha^{-1}	=	Per hectare
kg	=	Kilogram
LSD	=	Least Significant Difference
MoP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
NPK	=	Nitrogen, Phosphorus and Potassium
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
t	=	Ton
TSP	=	Triple Super Phosphate
viz.	=	Videlicet (namely)
Wt.	=	Weight

CHAPTER I

INTRODUCTION

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INTRODUCTION

Sweet Pepper (*Capsicum annum* L.) is a year-round international vegetable crop belongs to solanaceae family used in variety of ways for home consumptions, catering and industries (Obidiebube *et al.,* 2012). It is the second most important vegetable in the world after tomato. Sweet pepper is native to southern part of North America and southern South America (Gruben and Tahir, 2004). It is source of vitamin A, C and E. A 100 g of edible portion of pepper provides 24 Kcal of energy, 1.3 g of protein, 4.3 g of carbohydrates and 0.3 g of fat (Matsufuji *et al.*, 1998).

It has introduced in Bangladesh for several years but not much familiar by the people or farmers. There is a good scope for its large-scale cultivation in Bangladesh for increasing vegetable diversification and to meet vegetable demand of the country's people. The nutritional quality of the fruits, especially as an excellent source of antioxidants- ascorbic acid, carotenoids and phenolic compounds makes the daily intake of pepper a health protecting factor in the prevention of chronic human degenerative and systemic sicknesses including cancer, diabetes, liver cirrhosis and cardio-vascular diseases (Navarro *et al.,* 2006). Sweet pepper is famous for its pleasant aromatic flavour, pungency and high coloring substance. It is used very widely in culinary, pharmaceutical and beverage industries (Islam *et al.*, 2017).

Water is a natural resource and essential for crop production. Production of vegetable is hampered in winter due to lack of irrigation as well as minimum rainfall. Most determinate crops are sensitive to water stress especially at the time of floral initiation, during flowering, and to a lesser extent, during fruit development (Hegde, 2008). In the winter season, the conservation of soil moisture may help in preventing the loss of water through evaporation from the soil facilitating maximum utilization of moisture by the plants. Mulching practices help to conserve soil moisture by reducing evaporation and control weeds effectively by reducing physiological functions of weed like germination, root, shoot and stem growth (Farjana *et al.*, 2019).

Mulching covers the soil surface, and hence, it is helpful in maintaining the soil temperature which is beneficial for overall crop growth. Many studies demonstrated that the application of mulch could keep the soil cool during very hot climatic conditions (Kader *et al.*, 2019; Long *et al.*, 2001; Fraedrich and Ham, 1982), while at normal/warm temperature in chilling days (Kader *et al.*, 2019). The temperature extremes affect the newly growing roots of plants adversely reducing the uptake of nutrients and water (Goulet, 1995). Therefore, the judicious maintenance and regulation of soil temperature is a very critical factor for optimum plant growth. However, in hot and dry conditions such as in deserts, mulches decrease the temperature by 10°C (barren soil) (Martin and Poultney, 1992).

Sixteen elements are known to be vital for the growth and development (Silva and Uchida, 2000) and inadequate supply of these nutrients leads to a reduction in yield. Therefore, plants should be fed with the nutrients continuously in order to get a higher yield. Nutrients are provided to the plants through both soil and foliar. Foliar application is the quickest and an excellent method of supplying plant nutrients (Fageria *et al.*, 2009). Irregular nutrients management is mainly responsible for low production because application of different nutrients in required amount is given no attention. Many production problems in chillies are related to micronutrients deficiency (Bose and Tripathi, 1996). Micronutrients are needed in very little quantity but are very important for proper growth of plants (Mousavi, 2009). Less production of chilli might also be because of insufficient amount of zinc and boron present in soil of chilli producing regions. It has been reported that yield of capsicum (*Capsicum annuum* L.) is affected because of unavailability of required micronutrients in soil (Abdou *et al*., 2011).

Micronutrients are usually required in minute quantities but essential for various activities; particularly zinc and boron play vital in the growth and development of plants due to catalytic effect on many metabolic processes (Abdou *et al*., 2011). Zinc activates the electrophile and nucleophiles as a component of plant carbonic anhydrase and many other photosynthetic enzymes, which influences the photosynthetic efficiency, chlorophyll structure and content. It is also involved in sucrose and starch formation, protein metabolism, membrane integrity, auxin metabolism, defense mechanism, flowering and seed production of crop plants (Ballabh *et al.*, 2013). Boron influences the absorption of NPK and its deficiency changes the equilibrium of optimum of those three macronutrients. Boron (B) is taken up by plant roots as the neutral molecule H_3BO_3. B is important for both flower development and initial fruit or seed set (Borghi and Fernie, 2017) and maintaining the structural integrity of cell wall and cell membranes (Zhang *et al.*, 2014). It enhances the percentage of fruit-set by promoting pollen germination and elongation of pollen tube. The first signs B deficiency is the decrease in seed or fruit set. The first signs B deficiency is the decrease in seed or fruit set (Abdalla and El-Khoshiban, 2007).

Therefore, it is clear that the growth and yield of sweet pepper can be increased by suitable mulch materials and judicious foliar application of micronutrients. But only a little information on sweet pepper research regarding mulch materials and foliar application of micronutrients is available in Bangladesh.

Keeping the above facts in view the present experiment was undertaken with following objectives:

i. To investigate the effect of different mulch materials on growth and yield of sweet pepper under net house.

ii. To observe the influence of foliar application of micronutrients on growth, yield attributes and yields of sweet pepper under net house.

iii. To find out the suitable combination of mulch materials and foliar application of micronutrients for better growth and higher yield of sweet pepper under net house.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The yield of sweet pepper may be increased through appropriate combination of different mulch materials and foliar application of micronutrients. Though sweet pepper is cultivated in many parts of our country, very little research work has so far been conducted on the suitable mulch materials with optimum levels of foliar application of micronutrients. Research findings regarding the growth and yield of sweet pepper as influenced by different mulch materials and foliar application of micronutrients under Bangladesh condition is very limited. With the above background, some of the pertinent works have been reviewed in this chapter.

2.1 Effect of mulch materials

Bijalwan *et al.* (2021) conducted a field study in Himachal Pradesh during the year 2017-18 with twelve treatments in order to evaluate the effect of planting methods, mulches and NAA application on growth and yield components of bell pepper (*Capsicum annuum* L.). Results showed that all the treatments significantly influenced the yield and yield contributing traits. Maximum plant height (73.66 cm), minimum days to 50 per cent flowering (27.25), maximum fruit length (7.35 cm), fruit breadth (6.39 cm), fruit weight (51.26 g), number of fruits per plant (25.10), yield per plot (53.90 kg) and yield per hectare (380.25 q) was recorded in T3 (Raised bed + silver polythene mulch + NAA application @ 15 ppm 30 and 45 day after planting). Maximum soil moisture and temperature was recorded in plots which were covered with silver and black polythene mulches. Similar plots also produced maximum yield.

Idaryani *et al.* (2021) conducted a study to determine the effect of mulch use and frequency of watering on the growth and yield of chilli plants. The research was conducted in Lampoko Village, Barebbo District, Bone Regency, in May-July 2017, used factorial randomized block design with two factors. The first factor was the application mulch (without mulch, organic mulch, and plastic mulch) and the second factor was the frequency of watering (once a day, two times a day, and once in two days). The data obtained were then analyzed for variance and continued with Duncan's Multiple Range Test (DMRT). The results showed that the treatment of mulch utilization significantly affected plant height 30 and 60 DAP, number of fruit, weight fruit, and fresh plant weight. The treatment of the frequency of watering significant effect on plant height 30 and 60 DAP, number of fruit, weight fruit, and fresh plant weight. In general, the best growth and production of chilli were obtained in the treatment of the application of plastic mulch with a frequency of watering once a day namely 13.03 t ha^{-1}.

Rani *et al.* (2020) conducted an on–farm trial on various farmers field in different villages of Araria district during financial year 2016-17. This trail was conducted to overcome weed infestation during cultivation of chilli in farmer's field. It leads to reduction in yield; quality of produce is inferior as compared to better quality produce, increased the cost of cultivation due to manual hand weeding by laborers and reduced the benefit cost ratio. The trial was conducted in randomized block design with three treatments and ten replications. The different treatments are Technology option-1 is farmers practice, Technology option-2 is use of paddy straw as mulch and Technology option-3 is use of bicolor silver/black plastic 25 micron thickness as mulch material. Maximum plant height recorded was 78.10 cm in case of use of bicolor plastic mulch as compared to 72.90 cm in case of paddy straw as mulch material and 66.10 cm in case of control. The highest average number of fruits per plant was 175.40 in case of bicolor plastic mulch as compared to 163 fruits per plant in case of paddy straw mulch and 150.40 in case of control. The maximum average weight of fruit was 4.53gm, fruit yield per plant was 743.84 g and yield 89.66 quintal per hectare is recorded in case of bicolor plastic mulch as compared to 4.42gm per fruit, 662.57 g/plant and 84.24 quintal per hectare was found in case of paddy straw mulch and 3.61gm per fruit, 579.14 g per plant and 75.18 quintal per hectare was recorded in case of control.

Yasmin *et al.* (2020) conducted an experiment at Regional Agricultural Research Station (RARS), Jamalpur, Bangladesh during the period of 2017-18 and 2018-19 with the objectives to evaluate the effect of different mulch on soil temperature, soil moisture conservation and yield attributes of chilli. There were five treatments comprising T_1: no mulch, T_2: rice straw mulch @ 5 t ha^{-1}, T_3: water hyacinth mulch @ 5 t ha^{-1}, T_4: black polyethylene mulch and T_5: white polyethylene mulch. The results revealed that, all the mulch treatment had higher soil temperature and soil moisture content at 5 cm and 10 cm depth compared to no mulch treatment. Soil temperature was highest in black polyethylene mulch; it increased average soil temperature by about 5.7 °C at 5 cm depth and 5.1 °C at 10 cm depth compared to no mulch treatment at 120 Days. Rice straw mulch treatment recorded highest soil moisture, it increased average soil moisture about 27.87% at 5 cm depth and 28.57% at 10 cm depth over no mulch treatment. Rice straw mulch treatment produced highest green chilli yield (8.81 t ha^{-1}) which was 26.94 % increase over no mulch treatment (6.94 t ha^{-1}). Considering economic analysis, highest gross return (Tk. 352400 ha^{-1}), gross margin (Tk. 235400 ha^{-1}) and BCR (3.01) was obtained from same treatment T_2 i.e., rice straw mulch treatment.

Debbarma *et al.* (2019) conducted a study to quantify the effects of drip irrigation levels and black plastic mulch on bell pepper production under a naturally ventilated polyhouse in Tarai region of Uttarakhand during Rabi 2014-15. The experiment was laid out in randomized block design with three replications keeping four drip irrigation levels (100, 80, 60 and 40% of crop water requirement) and surface irrigation in conjunction with black plastic mulch and without mulch. It was observed that plant morphological parameters *viz.* plant height, fresh and dry weight of plant and root and fruit characters such as number of fruits per plant, average fruit weight, fruit length &diameter, polar and lateral circumstances of fruit and total yield were significantly increased by drip irrigation alone as well as in conjunction with black plastic mulch. Drip irrigation at 80% of crop water requirement gave the highest yield of fruits (83.22 t/ha), whereas it was the least (66.99 t/ha) in case of surface irrigation. The yield was further increased by the use of black polyethylene mulch (88.99 t/ha). It was also observed that drip irrigation both with and without plastic mulch registered much higher water use efficiency (WUE) compared to surface irrigation. The minimum water use efficiency of 142.4 kg ha^{-1} mm^{-1} was obtained for the plots receiving surface irrigation without the mulch. The use of black film in case of surface irrigation increased the WUE to 163.2 kg ha^{-1} mm^{-1}.

Lodhi *et al.* (2019) conducted a field experiment to study the effect of nutrients and mulching on fruiting and fruit characteristics of Bell pepper at Horticulture farm, Institute of Agriculture, Visva-Bharati, Sriniketan (West Bengal) during rabi season 2014-15. The experiment was laid out in Completely Randomized Block Design (CRBD) consisting of nine treatments. The treatment comprising of different combinations of nutrients and mulches i.e. Nitrogen (150 kg ha^{-1} and 200 kg ha^{-1}), Phosphorous (80 kg ha^{-1} and 120 kg ha^{-1}) and mulches (Paddy straw and water hyacinth each @ 7 t ha^{-1}) with three replications. The statistical analysis indicated that the fruiting and fruit characteristics of bell pepper were significantly influenced by nutrients and mulching. Highest number of fruits per plant (9.95), highest fruit weight (69.18 g), maximum fruit length (9.95 cm), diameter (7.37 cm) and volume (97.07 cm^3) were observed in the treatment T_6 with 200 kg N ha^{-1} + 80 kg P_2O_5 ha^{-1} + Paddy straw mulch @ 7 t ha^{-1}. Control condition indicated significantly lowest result than all other treatments.

Maida *et al.* (2019) carried out a research during *Rabi* season of 2017-2018 at the Horticulture complex, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur. The treatment of the experiment consisting of two-colored polyethylene mulch (black, silver/black) and with bare soil (without mulch) as control. Results showed that soil temperature under the various colored mulches was 2 to 4˚C warmer compared to bare soil. The highest soil temperature was recorded under black mulch (20.63). The plants grown on silver/black mulch produced Maximum plant heights (48.83 cm.), primary branches/plant (13.74), secondary branches/plant (21.13),early flowering (17.19), fruit length (8.74 cm), Fruit diameter (0.88 cm), average weight of fruit (4.49 g), number of fruits/plant (155.25), fruit yield/plant (744.14 g), fruit yield per plot (11.82 kg), ascorbic acid (269.07 mg/100 g), moisture depletion pattern % and soil temperature under different stages. Under without mulch condition, recorded maximum days taken to 50% flowering (24.58), maximum total soluble solids (2.38 ºBrix), weeds fresh weight (41.49 g) and weeds dry weight (11.48 g). In an attempt to reducing chemical input for weed control and increase to yield of chilli black and silver/black plastic mulch may be a good alternative for conventional without mulch.

Narayan *et al.* (2017) conducted a field experiment in kharif season at experimental farm, division of Vegetable Science, SKUAST-K, Shalimar to study the effect of mulching on growth and yield of chilli for three consecutive years 2013-15. Three levels of organic mulch as 6.0, 9.0 and 12.0 t/ha paddy straw and three forms of inorganic mulch as black double coated, white double coated and black single coated polythene of 30 micron thickness were used. Data was recorded on soil moisture, weed density, number of fruits, fruit length, fruit width, fruit weight and fruit yield. Economics of various treatments was also worked out and B:C ratio was calculated. Black plastic mulch (double coated) recorded the highest soil moisture retention (16.74%), lowest weed density (74.81g/plot dry weight), highest number of fruits (140/plant), with maximum fruit weight (9.99 g) and total fruit yield (463.08 q/ha). Mulching with double coated black polythene recorded highest B:C ratio of 3.49 hence may be stated as a viable tool to increase yield in chilli under temperate conditions.

Ocharo *et al.* (2017) conducted an experiment at the Crops Research Station of the Kenya Agricultural and Livestock Research Organization Alupe, Busia County. The experiment was performed to find out the most suitable mulching material and an ideal spacing for green pepper cultivation under Busia County Conditions. The experiment was laid out in a Factorial Randomized Block Design with three replications. The treatments comprised of four mulching materials viz. black plastic mulch, transparent plastic mulch, straw mulch and bare soil which was the control with three row spacings *viz.* 30 × 50 cm, 40 × 40 cm and 50 × 40 cm. Data collected was subjected to SAS statistical software for analysis and means separated using LSD at $P \leq 0.05$. Significant responses on plant height and number of branches per plant were observed for both seasons due to spacing and mulching treatments. The highest branches (6.97) per plant were recorded in the 40 by 40 cm spacing under the transparent mulch with the lowest (2.83) shown under the same spacing in the straw mulch of California Wonder variety. The widest spacing elicited the highest number of fruits per plant (7.37) in the black plastic mulch while only a mean of 1 fruit per plant was recorded in the mulch control during the short rain season. The highest fruit mean yield per plant of 1556 g and 1533 g was recorded in the widest spacing (50 by 40 cm) during the long and short rain seasons respectively. Therefore this study recommends the use of plastic mulches at wider spacing.

Zerga *et al.* (2017) conducted an experiment was carried out in randomized complete block design (RCBD) using three replications and four treatments. The effect of different mulching material such as grass, banana, plastic and control mulch on growth parameters (plant height, germination rate, leaf number of branch per plant,) of hot pepper was conducted for three months. Data was collected and compared by using LSD at significant level of 0.05. The result showed that the highest and lowest plant height was obtained for grass mulch (T_1) and control (T_4) on the other hand no plant height was registered for plastic mulch**.** Generally, from the result of this study we recommended that farmers use of grass mulch increase the rate of hot pepper seedling and growth performance by maintain soil temperature, soil moisture and provide good air circulation with in soil spores than other mulching materials. The awareness of farmers should be increased by providing adequate training regarding with the type of appropriate mulching material. So, they can produce proper operation during the growth of paper to avoid the infestation of weed by mulching. According to analysis of variance there was significant different among treatments on the number of braches per plant and also results of the analysis of variance indicated that different mulching material were shown significantly ($p>0.05$) effect on plant height of pepper. However, there is no significant variation among the treatment for number of leaves. Since the recommended using vativar grass mulch until another investigation was done. This is a short term strategy; therefore, the study should be repeated over year.

Edgar *et al.* (2016) conducted an experiment to observe the influence of mulching materials on the growth and yield components of green pepper at Busia County in Kenya. The experiment was conducted during 2015 to assess the efficacy of black plastic, transparent plastic and straw mulch on growth and yield of green pepper. The treatments were black polythene mulch, transparent polythene mulch, straw mulch and bare soil as the control. The straw mulch elicited significantly vigorous growth of seedlings compared to the other treatments but had the lowest number of leaves unlike transparent mulch which had the most with 58. The widest stem circumference was observed on mulched plots as well as the plant height where the control recorded the lowest height. The black polythene mulch gave significantly ($P=0.05$) heavier fruits of 924.5 g/plant during the long rain and 681.1 g/plant in the short rain season. Unmulched plots of either variety had the lowest mass recorded for fruit in both seasons. The transparent mulch showed significantly ($P=0.05$) more seeds per fruit (196), longest fruit length (8.5 cm) and greatest fruit diameter (9.2 cm). Based on the experimental results the black polythene mulches had greatest effects on the growth, and yield of sweet pepper and showed superior performance among the plastic mulches in the study area and therefore are recommended.

Verma *et al.* (2016) carried out an experiment at Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh (India) during kharif season 2013 to study the effect of mulching and planting geometry on seed production in bell pepper (*Capsicum annuum* L.) in mid-hills of Himachal Pradesh. The planting geometry consists of row layouts and plant layouts. The treatment combinations comprised of four different mulches viz., no mulch, black-plastic mulch, silver-black plastic mulch (upper side of mulch is silver while lower side is black and crop residue mulch, three row layouts with constant population of 37037 plants ha^{-1} were recommended single row 60 × 45 cm^2 (single rows 60 cm apart and plants within rows are 45 cm apart, double row (75 + 45) × 45 cm^2, 75 cm between two double rows, 45 cm within two double rows and plants within rows are 45 cm apart, and double row (90 + 30) × 45 cm^2 (90 cm between two double rows, 30 cm within two double rows and plants within rows are 45 cm apart, and two plant layouts viz., rectangle/square, and triangle. The treatment combination of silver-black plastic mulch, double row (75 + 45) × 45 cm^2 and triangle method of planting was found superior over all other treatments in terms of growth characters, fruit and seed yield characters.

Musie *et al.* (2015) conducted an experiment in 2009/10 at Jimma University College of Agriculture and Veterinary Medicine under irrigation with the objective of determining the effects of different mulch types on growth of hot pepper varieties. The experiment consisted of three hot pepper varieties (Bako Local, Melka Awaze and Dube Medium) and three types of mulches (dry coffee husk, dry vetiver grass and dry banana leaves) laid out in Randomized Complete Block Design with three replications. Data were collected on growth of hot pepper varieties. The results indicated that the combined effects of mulching and varieties showed significant variation on growth of hot pepper. The interaction between Bako Local variety with dry coffee husk produced higher total leaf area (9089.94 cm/plant), larger leaf area index (4.33), longer fruit length 2 (13.10 cm) and higher fruit shape index value (6.24). Bako Local with dry vetiver grass produced the longer fruit length (13.89 cm) and higher fruit shape index. Variety Melka Awaze mulched with dry coffee husk produced maximum number of leaf per plant, higher number of fruit per plant. Melka Awaze with dry vetiver grass also gave higher number of fruit per plant. From this study it can be concluded that dry coffee husk and dry vetiver grass mulches combined with Melka Awaze variety have potential to increase the growth hot pepper under Jimma condition.

Tosala and Eshetu (2014) conducted an experiment in 2014 cropping season at JUCAVM research site under irrigation to determine the effect of different types of mulches on the germination and growth performance of local hot pepper. The experiment had four treatments: Dry banana leaves, dry Vetivar-grass, plastic and bare plot laid out using Randomized Complete Block Design (RCBD) each replicated three times. Data was collected on seedling emergency and growth performance of hot pepper. The results indicated that using different mulches did not show any significant difference on germination and growth performance of hot pepper. This result gives us two conclusion lines: the first line is telling us that using any type of mulching material do not have unique implication on the growth performance of hot pepper. However, the plastic mulches showed higher mean value in plant height, seedling emergency and number of plant. From this study, it is clear that even though the different mulching materials have no statistically significant differences on the growth performance of hot pepper still the plastic mulch showed better performance on seedling emergency, plant height and number of branch per plant under JUCAVM research site condition.

Komla (2013) investigated with the effects of organic mulches on growth and yield of sweet pepper at the University of Ghana Forest and Horticultural Crops Research Centre, Okumaning near Kade. Two field experiments were conducted in the raining season, that is from July, 2012 to December, 2012 and in the dry season from December, 2012 to March, 2013. In both experiments four treatments; dry rice husks (RH), empty palm fruit bunches (EPFB) and cocoa pods husks (CPH) as mulches at the rate of 35t/ha each and a control (bare soil) were evaluated in a randomized complete block design with four replications. The results indicated that organic mulch application in both rainy and dry seasons significantly influenced soil temperature and suppressed weed growth. Soil moisture content was not significantly influenced by the mulch materials in the rainy season. However, in the dry season soils under mulched plots retained significant amount of soil moisture compared to soils under no mulch treatment. Organic mulch application in the rainy season did not significantly increase plant height, stem diameter, number of branches, number of leaves, leaf area as well as leaf area index of sweet pepper compared to the control. However, the application of organic mulch compared to the control resulted in increased plant height, canopy size and stem diameter in the dry season. Although weight of fruits per plant, mean fruit weight per plant, total fruit yield, fruit length and fruit width were not significantly increased by the application of organic mulch materials in the rainy season, mulching significantly influenced yield and yield components of sweet pepper in the dry season. Application of rice husk mulch was the most effective treatment in increasing the weight of fruits per plant, total fruit yield and mean fruit weight per plant.

Ashrafuzzaman *et al.* (2011) conducted a field study to evaluate the effect of coloured plastic mulch on growth and yield of chilli from October 2005 to April 2006. The plastic mulches were transparent, blue, and black and bare soil was the control. Different mulches generated higher soil temperature and soil moisture under mulch over the control. Transparent and blue plastic mulches encouraged weed population which were suppressed under black plastic. Plant height, number of primary branches, stem base diameter, number of leaves and yield were better for the plants on plastic. At the mature green stage, fruits had the highest vitamin-C content on the black plastic. Mulching produced the fruits with the highest chlorophyll-a, chlorophyll-b and total chlorophyll contents and also increased the number of fruits per plant and yield. However, mulching did not affect the length and diameter of the fruits and number of seeds per fruit. Plants on black plastic mulch had the maximum number of fruits and highest yield. Thus, mulching appears to be a viable tool to increase the chilli production under tropical conditions.

Siwek *et al.* (1994) investigated with the effect of white and black polyethylene mulches on the microclimate in plastic tunnels and on the growth and yield of green pepper was investigated in 1990 and 1991. Plants were transplanted in the first ten-day period of May and fruits were harvested at the stage of physiological maturity from August 15-October 15. Temperature measurements at 8.00 a.m. showed that heat accumulation in the soil was greater under the black mulch. As related to bare soil, the temperature was higher by 0.5°C on the average, though the differences sometimes reached 1.5-2.0°C. Under white mulch, the temperature of the soil was lower than that of bare soil by 0.5°C on the average. White mulching resulted in a

187.6% increase in reflected physiologically active radiation (PAR) as compared with bare soil in the tunnel. The marketable yield of plants grown over white mulch was higher by 6.1% and over black by 10.3%. The average weight per fruit of mulched plants was also increased.

2.2 Effect of micronutrients

Khan *et al.* (2021) carried out a study entitled "effect zinc and boron on the growth and yield of chilli" at Agriculture Research Institute Mingora (ARI) Swat in summer 2016 in Randomized Complete Block Design (RCBD) having two factors replicates three times. Four levels boron (0, 1.0, 2.0 and 3.0 kg per hectare) and three levels of zinc (0, 1.5 and 3.0 kg per hectare). Foliar application of boron significantly influenced all parameters. Maximum number of fruits plant^{-1} (117.01), fruit length (8.98 cm), fruit weight plant^{-1} (622.21 g), yield tons ha^{-1} (2.71 tons) and 1000 seed weight (3.47 g) were observed by the foliar spray of boron @ of 3 kg per hectares. While in case of zinc maximum number of fruits per plant (113.99), fruit length (9.45 cm), fruit weight plant^{-1} (660.19 g), yield tons ha^{-1} (2.85 tons ha-1) and 1000 seed weight (3.54 g) were recorded in the plot to which received zinc @ of 3 kg per hectares. It is concluded from the results that foliar application of boron and zinc should be used @ of 3 kg per hectares for better chilli production in the agro-climatic conditions of Swat.

Ashraf *et al.* (2020) carried out an experimental trial to find the impact of foliar feeding of zinc and boron on flourishment and production of green chilli (*Capsicum frutescens* L.). Experiment was designed according to Randomized Complete Block Design (RCBD). Moreover, ten treatments and four replications were considered. Each treatment contained ten plants. Vegetative and reproductive of chilli hybrid cultivar BSS-410 were observed for data collection. Results revealed that maximum plant height (76.18 cm), stem thickness (1.78 cm), highest fruit weight (5.39g), maximum number of seeds per fruit (158.25), highest TSS value (10.63 °Brix) and highest pH value (5.68) was observed in T_9 while T_8 had maximum number of branches (36), maximum fruit pedicel length (3.17 cm), highest value of fruit length (12.49 cm), maximum fruit yield per plant (1113 g), maximum fruit yield per hectare (51.15 tons), highest value of 100 seeds weight (0.3250 g), Hence, it was concluded that foliar application of zinc and boron @ $ZnSO_4 + B_2O_3$ (0.75 + 0.6 g) per liter of water increased yield characters up to maximum and this dose can be recommended to farmers to get more yield and ultimately increase their profit.

Assi *et al.* (2020) conducted a field experiment in the non-heated plastic house at Al-Mussiab Technical College for the autumn season 2017 to study the response of sweet pepper (Qurtuba cultivar) *Capsicum annuum* L. to foliar spraying with two typed of Nano fertilizers in loamy sand soil. A factorial experiment was designed according to the full RCBD design, and the middles are compared by choosing the least significant difference LSD and a significant level of 5%. The Iron-Nano at four levels (0, 1, 2, and 3 g L^{-1}) and four levels of Nano-zinc fertilizer (0, 1, 2, and 3 g L-1) with three replicates, (2 g L^{-1} Nano-Fe). The results indicated to the excelling of the spraying treatment was superior (2 g L^{-1}) which significantly increased in plant height, number of fruit branches, leaf area of plant, dry weight of vegetative group, leaf content of chlorophyll, nitrogen, phosphorus and potassium. The number of fruits, fruit weight, and early and total yield with an increase percentage of (30.40, 50.82, 16.55, 17.97, 25.46, 38.19, 31.37, 38.19, 16.17, 18.50, 34.69, and 40.57%) for the above traits sequentially. which is the same behavior as the spraying of zinc Nano at a concentration of (2 g L^{-1}) for the traits of plant height, number of fruit branches, dry weight of the vegetative group, leaf content of chlorophyll, nitrogen and potassium and the number of fruits and fruit weight and the early and total yield with increase Percentage (25.55, 39.95, 27.93, 36.65, 29.53, 26.0, 20.38, 15.95, 40.43 and 41.78%) sequentially as compared to the control treatment. On the other hand (3 g L^{-1}) was excelled in spraying treatment with Zinc Nano, in the traits leaf area and leaf content of phosphorus, where the percentages of increase amounted of (18.17% and 24.53%) sequentially. As for interaction treatments, it showed excelling the spraying treatment with a mixture of iron and zinc Nano (2 g L^{-1} + 2 g L^{-1}) by giving it the highest values for all the above traits.

Kumar *et al.* (2020) carried out an experiment to study the response of different concentration of zinc and boron alone and in different combination on chilli cv. NP.46A and revealed that the treatment combination have great influence on the growth and yield of chilli as compared to control. Combined spraying of 0.75% Zn and 0.25% boron twice at 45 and 65 days after transplanting gave maximum green as well as dry yield. Spraying of 0.75% zinc alone was also found to be effective in improving the growth and yield.

Nawrin *et al.* (2020) conducted an experiment to observe the effects of boron (B) and vermicompost (VC) on growth and yield of chilli (*Capsicum annum* L.) and nutrient accumulation in its fruits. The highest plant height (22 cm), leaf number per plant (73), leaf area (502.53 cm^2/plant), dry weight (22.27 g/plant), fruit length (8.97 cm), fruit number per plant (6), fruit yield (11.76 g/plant) were recorded in B 0.5 kg/ha + VC 5 ton/ha at harvest. The results of growth and yield of Chilli varied significantly ($p<0.05$) and increased with time. The total nutrient concentrations in the fruits were measured and varied significantly ($p<0.05$). The highest concentration of total P (0.028 %), K (2.50%), S (0.20 %), Cu (8.0 mg/kg), Fe (410 mg/kg) and Mn (0.80 mg/kg) in the fruit were observed in B 0.5 kg/ha + VC 5 ton/ha treatment and total N (0.41 %) and Zn (3.50 mg/kg) were found in B 1.5 kg/ha + VC 5 ton/ha treatment. The overall best growth, yield and nutrient accumulation in the fruits of chilli was achieved in B 0.5 kg/ha + VC 5 t/ha treatment.

Thennakoon *et al.* (2020) conducted a study to evaluate the effect of foliar application of Mn, Zn and Cu on growth and yield of chilli grown in Reddish Brown Earth soils (Rhodustalfs), in dry zone, Sri Lanka. Seven treatments were tested in a greenhouse as pot experiment. Nitrogen, phosphorus and potassium were added into all seven treatments. Manganese Zn and Cu were added separately as foliar application for three treatments. One treatment had all three elements and control treatment had only N, P and K but no anyadded elements. Since all micronutrients were added as their sulfate form, last two treatments had S with N, P and K to assess the effect of S on plant growth. Copper with N, P, K added treatment showed significantly higher growth and yield compared to other treatments. It showed about 25% yield increment compared to control treatment. Therefore, it can be concluded that application of Cu is beneficial to obtain a better yield in chilli in Reddish Brown Earth Soils (Rhodustalfs). However, further field studies are needed to confirm findings.

Salim *et al.* (2019) conducted two successive seasons of 2017 and 2018 were at the Experimental Station of the Faculty of Agriculture, Ain Shams University, Cairo, Egypt to study the response of hot pepper plant (*Capsicum annuum* L.) cv. Hot Chili growth, fruit setting, yield and some biochemical constituents linked with the yield and quality characteristics to foliar spraying with calcium chloride at 0, 1000 and 2000 ppm, boric acid at 0, 200 and 400 ppm and their combinations. Results indicated that all foliar applications of calcium chloride and boric acid treatments individual or in combination markedly increased the vegetative growth characteristics, fruit setting percentage and fruits yield of hot pepper plants. Foliar spraying with 2000 ppm of calcium chloride plus 200 or 400 ppm of boric acid treatments obviously gave the higher values of plant height, number of branches per plant, shoot fresh and dry weights, fruit setting, fruits yield/plant and fruits yield/feddan as well as total carotenoids, vitamin C and N, P and K concentrations compared to the check treatment in both tested seasons.

Agarwal (2018) carried out a field experiment to standardize agro-techniques for higher productivity of capsicum in cold arid region of Ladakh. The experiments consisted of effect of growing environments (viz., under-ground trench, polycarbonate green house, polyench and open condition) and micronutrients (zinc, boron, manganese, magnesium, and copper) spray on yield performance and quality of capsicum var. California Wonder, Pusa Deepti and Yolo Wonder. Results revealed the significant effect of growing environments on marketable traits of capsicum. Fruit yield was found maximum under triple layer polycarbonate greenhouse (634.0 g per plant) exhibiting 115% increment over open control (294.0 g per plant). Among the micronutrients spray, two sprays of zinc (100 ppm) or boron (100 ppm) were found best under greenhouse conditions for obtaining higher yield and quality of capsicum exhibiting fruit yield of 840.96 g per plant significantly superior over control (768.43 g per plant) irrespective of the variety. Interaction effects of micronutrients to variety were significant for marketable traits of capsicum. In case of seed recovery, polycarbonate greenhouse was found best exhibiting the highest seed yield (4.01 to 4.39 g/plant) with better test weight (5.62 to 5.76 g).

Harris *et al.* (2018) conducted an experiment to study the effect of foliar application of boron (B) and magnesium (Mg) on growth and yield of green chilli (*Capsicum annum* L.) cv. MIPC-1. Foliar application of Boron and Magnesium (T_0) Control; (T_1) B = 50 ppm; (T_2) B = 100 ppm; (T_3) B = 150 ppm; (T_4) Mg = 50 ppm; (T_5) Mg= 100 ppm; (T_6) Mg = 150 ppm; (T_7) B (50 ppm) + Mg (50 ppm); (T_8) B (100 ppm) + Mg (100 ppm); (T_9) B (150 ppm) + Mg (150 ppm) was done. The sources of Boron and

Magnesium were boric acid (H_3BO_3) and Magnesium Sulphate ($MgSO_4.7H_2O$).The treatments were laid out in a Completely Randomized Design (CRD) and replicated four times. All the agronomic practices were carried out in accordance with Department of Agriculture, Sri Lanka. Maximum plant height (98 cm), number of branches (18 plant^{-1}), number of leaves (25 plant^{-1}), number of flowers (29 plant^{-1}), total dry weight (66 plant^{-1}), number of fruits (24 plant^{-1}), and unripe fruit yield (333 plant^{-1}) were observed with the foliar application of Boron (H_3BO_3) + Magnesium ($MgSO_4.7H_20$) at 100 ppm and minimum was found in the control treatment. Foliar application of Boron (H_3BO_3) + Magnesium ($MgSO_4.7H_20$) at 100 ppm increased yield by three-fold than that of control treatment. Therefore, it is concluded that combined application of B + Mg at 100 ppm was found to be effective in enhancing plant growth and fruit yield of chilli.

Sarafi *et al.* (2018) investigated the effect of boron concentration in nutrient solution on total uptake of the various nutrients and their utilization efficiency in pepper plants (*Capsicum annuum* L.). Four cultivars (Osho, Solario, Odysseo and Arlequin) were treated with 0.5-10 mg B L^{-1}. Each treatment consisted of five replications with 3 plants and after 20, 40 and 70 days in culture one plant per pot was removed, divided into leaves, shoots and roots and analyzed. The cultivars Odysseo and Arlequin have the greatest total phosphorus absorption at 0.5-2.5 mg B L^{-1} and more Ca at 1-2.5 mg B L^{-1}, while Odysseo absorbed more magnesium (Mg) per plant at 1 mg B L-1 and 70 d per plant than the other cultivars. Furthermore, Solario, Odysseo, and Arlequin absorbed at 70 days more B. Differences were recorded also among the cultivars concerning the rest of the nutrients. The maximum nutrient use efficiency of Solario and Osho for phosphorus and potassium was recorded at 5 mg B L^{-1} and in Solario for calcium. Boron use efficiency was maximum for Solario, Osho and Odysseo at 0.5 mg B L^{-1} and for Fe at 10 mg B L^{-1} for all the cultivars. The effect of boron on magnesium, manganese and zinc use efficiency was variable.

Singh *et al.* (2017) conducted an experiment to study the response of growth and yield of poly house grown capsicum cultivar "Indira" (*Capsicum annum* L.) to different applications of humic acid and micro nutrients. There were seven treatments which laid out in completely randomized design with three replications. Analysis of variance showed there were significant differences for all the characters studied during experimentation. Among the different treatments applied, T_7 (RDF + soil application of humic acid 10 kg/ha + foliar application of humic acid 0.1% + micronutrient mixture) was found statistically superior to enhance plant height (103.91 cm), number of branches per plant (9.33), leaf area (391.30 cm^2), fruit weight (174.28 g), number of fruits per plant (22.07), volume of fruit (376.57 cc), specific gravity (0.58 g/cc) and yield per plant (3.85 kg).

Shil *et al.* (2013) conducted a field trial on chilli (cv. *Bogra* local) in Grey Terrace Soil under AEZ-25 (Level Barind Tract) at Spice Research Centre, Bogra during rabi seasons of 2005-2006, 2006-2007 and 2007-2008. The objectives were to evaluate the response of chilli to zinc and boron and to find out the optimum dose of zinc and boron for maximizing the yield. Treatments for this study comprised of four levels each of zinc (0, 1.5, 3.0, and 4.5 kg/ha) and boron (0, 1.0, 2.0, and 3.0 kg/ha) along with a blanket dose of N_{130} P_{60} K_{80} S_{20} Mg_{10} kg/ha. The experiment was set up in a randomized block design (factorial) with 3 replications. The integrated use of zinc and boron was found superior to their single applications. The interaction effect between zinc and boron was significant in case of yield of dry chilli and weight of ripe chilli/plant. The highest yield (1138 kg/ha) was recorded from Zn_3B_1 kg/ha, which was closely followed by Zn_3B_2, $Zn_{4.5}B_2$ and the lowest (703 kg/ha) in control (Zn_0B_0). The yield benefit over control varied from 4.4 to 61.9% due to interaction effect. Consecutive three years studies showed almost similar trend of results. However, from regression analysis, the optimum-economic dose of zinc was found to be 3.91 kg/ha whereas it was 1.70 for boron. Hence, a package of ($Zn_{3.91}B_{1.70}$ kg/ha) along with the said blanket dose may be recommended for maximizing the yield of chilli in the study area.

Dursun *et al.* (2010) conducted a greenhouse experiment to study yield and quality response of three vegetables to B addition (0, 1, 2, 3, and 4 kg B ha^{-1}). The optimum economic B rates (OEBR) were 2.3, 2.6, 2.4 kg B ha^{-1}, resulting in soil B concentrations of 0.33, 0.34 and 0.42 mg kg^{-1}. Independent of plant species, B application decreased tissue nitrogen (N), calcium (Ca), and magnesium (Mg) but increased tissue phosphorus (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) concentrations. We conclude that a B addition of 2.5 kg ha^{-1} is sufficient to elevate soil B levels to non-deficient levels. Similar studies with different soils and initial soil-test B levels are needed to conclude if these critical soil test values and OEBR can be applied across the region.

El-Mohsen *et al.* (2007) investigated the response of pepper plants cv. California wonder to foliar application of some micro-elements Fe, Mn, and Zn. Results indicated that application of Fe 1 g/L + Mn 1 g/L + Zn 1 g/L treatment gave the maximum tallest sweet pepper plants and gave the highest number of leaves and branches. The same treatment gave the highest fresh and dry weights of leaves as well as gave the highest total yield. Moreover, the highest values of N, P and K (%) were achieved using the mixture of Fe, Mn and Zn treatment. However, the highest value of Fe and Mn (ppm) were true when used 2 g Fe/L in the first and second seasons, respectively. The highest significant N, P and K (%) as well as Fe, Mn and Zn were recorded by using (Fe 1 g/L, Mn 1 g/L, Zn 1 g/L) treatment.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter describes the materials and methods which were used in the field to conduct the experiment entitled “Effect of mulch materials and foliar application of micronutrients on the growth and yield of sweet pepper under net house” during the period from November 2020 to April 2021. The materials and methods that were used for conducting the experiment have been presented in this chapter. It comprises a short description of experimental site, soil and climate, variety, growing of the crops, experimental design and treatments and collection of data presented under the following headings:

3.1 Site description

The research work was conducted at Horticulture Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from November 2020 to April 2021. The location of the site was 23°74′ N Latitude and 90°35′ E Longitude with an elevation of 8.2 meters from the sea level (Anon, 1987) and presented in Appendix I.

3.2 Soil characteristics

The texture of the soil in the experimental field was silty loam. The soil in the experimental area is part of the Modhupur Tract (UNDP, 1988) and belongs to AEZ No. 28. Before conducting the experiment, a soil sample from the experimental plot was obtained from a depth of 0-30 cm and examined at the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka which is shown in Appendix II.

3.3 Climate and weather

The climate of the experimental site was under the subtropical climate with three distinct seasons: winter from November to February, pre-monsoon or hot season from March to April, and monsoon season from May to October (Edris *et al.*, 1979). The Bangladesh Meteorological Department, Agargoan, Dhaka, provided details of the meteorological data collected during the experiment, which are presented in Appendix III.

3.4 Crop/Plating material

The seed of variety BARI Misti morich-2 was collected from Bangladesh Agricultural Research Institute (BARI), Joydepur, Gazipur, Bangladesh.

3.5 Treatments under the investigation

The experiment consisted of two factors *viz.* different mulch materials and foliar application of micronutrients

Factor A: Mulch materials

M_0= No mulch (control)

M_1= Black polyethylene mulch and

M_2= Rice straw mulch

Factor B: Foliar application of micronutrients

N_0= Control (No micronutrients)

N_1= Zn @ 0.6% as $ZnSO_4$ and

N_2= B @ 0.6% as H_3BO_3

There are 9 treatment combinations such as M_0N_0, M_0N_1, M_0N_2, M_1N_0, M_1N_1, M_1N_2, M_2N_0, M_2N_1 and M_2N_2.

3.6 Design and layout of the experiment

The two-factorial experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was divided into three equal blocks. Each block was divided into 9 plots where 9 treatments combination were distributed randomly. There were 27 unit plots altogether in the experiment. The size of each plot was 1.50 m × 1.20 m. The distance maintained between two blocks and two plots were 1.00 m and 0.50 m, respectively. The plots were raised up to 10 cm. In the plot with maintaining distance between row to row and plant to plant were 40 cm and 50 cm, respectively.

3.7 Seedbed preparation

Seedbed was prepared on 2nd week of October 2020 for raising seedlings of sweet pepper and the size of the seedbed was 3 m × 1 m. For making seedbed, the soil was well ploughed to loosen friable and dried masses to obtained good tilth. Weeds, stubbles and dead roots were removed from the seedbed. Cowdung was applied to prepared seedbed. The soil was treated by Sevin 50WP @ 5 kg ha^{-1} to protect the young plants from the attack of mole crickets, ants and cutworm.

3.8 Seed treatment

Seeds were treated by Provax 200WP @ 3g kg^{-1} seeds to protect some seed borne diseases.

3.9 Seed sowing

Seeds were sown on 3 November, 2020 in the seedbed. Sowing was done thinly in lines spaced at 5 cm distance. Seeds were sown at a depth of 2 cm and covered with a fine layer of soil before being lightly watered with a water can. Following that, the beds were covered with dry straw to keep the required temperature and moisture levels. The dry straw cover was removed as soon as the seed sprout emerged. When the seeds germinated, white polythene was used to provide shade to protect the young seedlings from the scorching sun and rain.

3.10 Raising of seedlings

Light watering and weeding were done several times. No chemical fertilizers were applied for raising of seedlings. Seedlings were not attacked by any kind of insect or disease.

3.11 Land preparation

The plot selected for the experiment was opened with a power tiller in the 2^{nd} week of November 2020 and left exposed to the sun for a week. To achieve good tilth, the land was harrowed, ploughed, and cross-ploughed several times after one week, followed by laddering. Weeds and stubbles were removed and a desirable tilth of soil was obtained for seedling transplanting. Drainage channels were built around the land to prevent water logging caused by rainfall during the study period. When the plot was finally ploughed, the soil was treated with Furadan 5G @ 15 kg ha^{-1} to protect the young seedlings from cut worm attack.

3.12 Application of manures and fertilizers

Total amount of organic manure, TSP and MoP were applied during final land preparation and urea was applied at equal three installments i.e. 15, 30 and 45 DAT. Zinc and boron fertilizer used as a foliar application. Foliar application of zinc and boron micronutrients at three times during vegetative stage, flower initiation stage and fruit setting stage when fruit attained marble shaped.

The following doses of fertilizers and manures were used in this experiment:

Fertilizers	Manures	Doses (per hectare)
	Cowdung	10 t
Urea		250 kg
TSP		330 kg
MoP		250 kg
Zinc		As par treatment
Borax		As par treatment
Gypsum		110 kg

3.13 Transplanting of seedlings

The seedbed was watered before uprooting the seedlings to minimize the damage of roots. 27 days old healthy seedlings were transplanted at the spacing of 50 cm × 40 cm in the experimental plots on 1 December 2020 as per treatment. Planting was done in the afternoon. For better establishment, light irrigation was applied immediately after transplanting around each seedling. Watering was done for up to five days until they could establish their own root system.

3.14 Intercultural operations

3.14.1 Gap filling

Very few seedlings were damaged after transplanting and new seedlings from the same stock were replaced these.

3.14.2 Weeding

The plants were kept under careful observation. Weeding was done at two times. First weeding was done two weeks after transplanting. Another weeding was done after 30 days of first weeding.

3.14.3 Irrigation

For better establishment, light irrigation was applied immediately after transplanting around each seedling. Watering was done for up to five days until they could establish their own root system. Irrigation was given based on the moisture content of the soil. During the crop period, irrigation was performed four times.

3.14.4 Insects and diseases management

The crop was attacked by cutworms, mole cricket and field cricket during the early stage of growth of seedlings in the month of December. This insect was controlled by spraying Dursban 20 EC @ 0.1%. Some of plants were infected by *Alternaria leaf* spot diseases caused by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2 g/l of water was sprayed in the field. The diseased leaves were also collected from the infested plant and removed from the field.

3.15 Harvesting

Harvesting of fruits was started at 80 DAT (20 February, 2021) and continued up to final harvest (22 April, 2021) based on the marketable sized of fruits. Harvesting was done by hand picking.

3.16 Collection of data

The data pertaining to following characters were recorded from five plants randomly selected from each plot. The following parameters were studied for the present experiment.

3.16.1 Plant height (cm)

Plant height was recorded at 45, 65, 85 days after transplanting (DAT) and at harvest by using meter scale. Height was measured from ground level to the tip of the largest leaf of an individual plant. Thus mean value of the five selected plants per plot was considered as the height of the plant and was expressed in centimeter.

3.16.2 Number of leaves per plant

The total number of leaves per plant was counted from each selected plant of sweet pepper. Data were recorded as the average of 5 selected plants at random from the inner rows of each plot from 45 DAT to 85 DAT at 20 days interval and at final harvest.

3.16.3 Leaf length per plant (cm)

Length of leaf was measured at harvest from the base of the petiole to the tip of leaf with a meter scale and was recorded in centimeter.

3.16.4 Leaf breadth per plant (cm)

Breadth of leaf was measured at harvest from the widest part of the lamina by a meter scale and was expressed in centimeter.

3.16.5 Days from transplanting to 1st flowering

Difference between the dates of transplanting to the date of 1st flower emergence of a plot was counted and recorded.

3.16.6 Days from transplanting to 50% flowering

Difference between the dates of transplanting to the date of flowering of a plot was counted as days to 50% flowering. Days to 50% flowering was recorded when 50% flowers of a plot were at the flowering stage.

3.16.7 Number of flowers per plant

The number of flowers per plant was counted from each plot after flowering and recorded per plant basis.

3.16.8 Number of fruits per plant

The number of fruits per plant was counted after setting of fruits and recorded per plant basis.

3.16.9 Length of fruit (cm)

The length of individual fruit was measured in one side to another side of fruit from five selected fruits with a meter scale and average of individual fruit length recorded and expressed in centimeter (cm).

3.16.10 Diameter of fruit (cm)

The diameter of individual fruit was measured in several directions with meter scale and the average of all directions was finally recorded and expressed in centimeter (cm).

3.16.11 Individual fruit weight (g)

The weight of individual fruit was recorded in gram (g) by a beam balance from all fruits of selected three plants and converted individually.

3.16.12 Fruit yield per plant (kg)

Fruit yield per plant was recorded in gram by a multiplying individual fruit weight and number of fruits/plant by a digital weight machine. Fruit weight per plant was expressed in kilogram.

3.16.13 Fruit yield per plot (kg)

Yield of sweet pepper per plot was recorded as the whole fruit per plot and was expressed in kilogram.

3.16.14 Fruit yield per hectare (t)

Yield per hectare of sweet pepper was calculated by converting the weight of plot yield into hectare and was expressed in ton.

3.16.15 Total soluble solids

For total soluble solids content, five mature fruits were chosen and a 1 inch by 1 inch center piece of each fruit was squeezed and the obtained juice was placed on a digital hand-held pocket refractometer (ERMA- 0-32°B, Tokyo, Japan) at room temperature. Every single fruit was blended and juice was collected to measure °brix.

3.16.16 Vitamin C content

Vitamin-C was measured by Oxidation Reduction Titration Method. The leaf gel was blend and its extract was filtrated by Whatman No.1 filter paper. It was then mixed with 3% metaphosphoric acid solution. The titration was conducted in presence of glacial acetic acid and metaphosphoric acid to inhibit aerobic oxidation with dye solution (2, 6-dichlorophenol indophenol). The solution was titrated with dye. The observations mean will give, the amount of dye required to oxidize definite amount of L-ascorbic acid solution of unknown concentration, using L-ascorbic acid as known sample. It was measured in Horticultural Biotechnology and Stress Management Lab, Sher-e-Bangla Agriculture University, Dhaka.

3.17 Economic analysis

Cost of production was analyzed in order to find out the most economic return under different treatment combinations. All input costs, including the cost for lease of land and interest on running capital were considered for computing the cost of production. The interests were calculated @ 15% per year for 6 month. The cost and return analyses were done in details according to the procedure followed by Alam *et al.* (1989). The Benefit Cost Ratio (BCR) was calculated as follows:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

3.18 Data analysis technique

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package program MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

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The experiment was conducted to observe effect of mulch materials and foliar application of micronutrients on the growth and yield of sweet pepper under the soil and agro climatic condition of Sher-e-Bangla Agricultural University (SAU), Dhaka. Data on different growth and yield parameters were recorded. The Analysis of Variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix V-X. The results have been presented, discussed and possible interpretations were given in tabular and graphical forms. The results obtained from the experiment have been presented under separate headings and sub-headings as follows:

4.1 Plant height

Statistically significant variation was observed on plant height at 45, 65 and 85 DAT and at harvest due to different mulch materials (Table 1 and Appendix V). At harvest, the tallest plant (83.02 cm) was obtained from M_1 (Black polyethylene mulch) treatment and the shortest plant (68.10 cm) was revealed from M_0 (control) treatment. It was revealed that the plant height increased with the increase in days after transplanting (DAT) i.e., 45, 65, 85 DAT and at final harvest. It also revealed that the plant height increased with different levels of mulch materials as well. Similar results were also observed by Rani *et al.* (2020) who reported that mulches increases plant height than control. Komla (2013) reported that the application of organic mulch compared to the control resulted in increased plant height, canopy size and stem diameter in the dry season. Tosala and Eshetu (2014) also reported that plant height and number of branches showed higher mean when mulches used.

Table 1. Effect of mulch materials on plant height at different days after transplanting of sweet pepper

Treatments	Plant height (cm) at			
	45 DAT	65 DAT	85 DAT	Final harvest
M_0	8.63 c	17.14 c	32.15 c	68.10 c
M_1	10.27 a	21.69 a	45.53 a	83.02 a
M_2	9.63 b	20.18 b	35.39b	73.26 b
LSD(0.05)	0.3953	0.9396	1.3118	1.5882
CV%	4.20	4.82	3.51	2.14

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Micronutrients showed significant influence on the plant height of sweet pepper at 45, 65, 85 DAT and at final harvest (Table 2 and Appendix V). At harvest, the tallest plant (76.99 cm) was observed from N_1 (Zn @ 0.6% as $ZnSO_4$) treatment which was statistically identical to N_2 treatment. On the other hand the shortest plant (71.25 cm) was observed from N_0 (control) treatment. The result of the study was in coincided with the findings of Ashraf *et al.* (2020) who reported that micronutrients significantly affected plant height. They reported that foliar application of zinc and boron @ $ZnSO_4$ + B_2O_3 (0.75 + 0.6 g) per liter of water increased growth characters, yield characters up to maximum and this dose can be recommended to farmers to get more yield and ultimately increase their profit. Nawrin *et al.* (2020) also observed that best growth, yield and nutrient accumulation in the fruits of chilli was achieved in B0.5 kg/ha + VC5 t/ha treatment. Assi *et al.* (2020) reported that to the excelling of the spraying treatment was superior (2 g L^{-1}) which significantly increased in plant height, number of fruit branches, leaf area of plant, dry weight of vegetative group, leaf content of chlorophyll, nitrogen, phosphorus and potassium.

Table 2. Effect of foliar application of micronutrients on plant height at different days after transplanting of sweet pepper

Treatments	Plant height (cm) at			
	45 DAT	65 DAT	85 DAT	Final harvest
N_0	9.11 b	18.27 b	34.69 b	71.25 b
N_1	9.91 a	20.76 a	39.67 a	76.99 a
N_2	9.50 b	19.98 a	38.71 a	76.14 a
LSD(0.05)	0.3953	0.9396	1.3118	1.5882
CV%	4.20	4.82	3.51	2.14

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Significant influence was observed on plant height due to the combined effect of different mulch materials and foliar application of micronutrients (Table 3 and Appendix V). From the results of the experiment showed that the tallest plant height at harvest (85.73 cm) was observed from the treatment combination of M_1N_1 (Black polyethylene mulch + Zn @ 0.6% as $ZnSO_4$) which was statistically identical to M_1N_2 treatment combination. On the other hand the shortest plant at harvest (61.78 cm) was observed from M_0N_0 (control) treatment combination.

Table 3. Combined effect of mulch materials and foliar application of micronutrients on plant height at different days after transplanting of sweet pepper

Treatment Combinations	Plant height (cm) at			
	45 DAT	65 DAT	85 DAT	Final harvest
M_0N_0	7.77 e	14.19 f	29.19 f	61.78 e
M_0N_1	8.98 d	18.95 de	34.16 d	71.96 d
M_0N_2	9.13 d	18.28 e	33.10 de	70.58 d
M_1N_0	10.19 ab	20.93 bc	43.37 b	80.23 b
M_1N_1	10.75 a	22.72 a	47.86 a	85.73 a
M_1N_2	9.87 bc	21.44 ab	45.37 b	83.11 a
M_2N_0	9.37 cd	19.69 cde	31.52 e	71.73 d
M_2N_1	10.00 bc	20.62 bc	37.00 c	73.30 cd
M_2N_2	9.51 bcd	20.23 bcd	37.66 c	74.75 c
$LSD_{(0.05)}$	0.6847	1.6275	2.2721	2.7508
CV%	4.20	4.82	3.51	2.14

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

4.2 Number of leaves per plant

Significant variation was observed on number of leaves per plant of sweet pepper due to different mulch materials under the experiment (Table 4 and Appendix VI). At harvest, the maximum number of leaves per plant (131.15) was obtained from M_2 (rice straw mulch) treatment where minimum number of leaves per plant (115.46) was observed from M_0 (control) treatment. Ashrafuzzaman *et al.* (2011) reported that plant height, number of primary branches, stem base diameter, number of leaves and yield were better for the mulch materials.

Table 4. Effect of mulch materials on number of leaves per plant at different days after transplanting of sweet pepper

Treatments	Number of leaves per plant at			
	45 DAT	65 DAT	85 DAT	Harvest
M_0	7.46 c	18.57 c	56.89 c	115.46 c
M_1	9.43 b	19.96 b	64.57 b	122.82 b
M_2	10.33 a	23.24 a	70.29 a	131.15 a
$LSD_{(0.05)}$	0.4113	0.9700	0.6883	1.3438
CV%	4.58	4.76	5.09	4.10

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Number of leaves per plant showed significant variation on due to the influence of foliar application of micronutrients (Table 5 and Appendix VI). At harvest, the maximum number of leaves per plant (125.83) was observed from N_1 (Zn @ 0.6% as $ZnSO_4$) treatment. On the other hand the minimum number of leaves per plant (120.74) was observed from N_0 (control) treatment. Harris *et al.* (2018) found the similar results. They reported that maximum number of leaves, number of flowers was observed with the foliar application of Boron (H_3BO_3) + Magnesium ($MgSO_4.7H_2O$) at 100 ppm and minimum was found in the control treatment.

Table 5. Effect of foliar application of micronutrients on number of leaves per plant at different days after transplanting of sweet pepper

Treatments	Number of leaves per plant at			
	45 DAT	65 DAT	85 DAT	Harvest
N_0	8.38 b	19.05 b	61.66 c	120.74 c
N_1	9.60 a	21.44 a	66.02 a	125.83 a
N_2	9.25 a	21.28 a	64.07 b	122.86 b
$LSD_{(0.05)}$	0.4113	0.9700	0.6883	1.3438
CV%	4.58	4.76	5.09	4.10

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

Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Combined effect of mulch materials and foliar application of micronutrients significantly influenced by number of leaves per plant (Table 6 and Appendix VI). At harvest, the maximum number of leaves per plant (135.15) was achieved from M_2N_1 (Rice straw mulch + Zn @ 0.6% as $ZnSO_4$) treatment combination. On the other hand the minimum number of leaves per plant (113.17) was observed from M_0N_0 (control) treatment combination.

Table 6. Combined effect of mulch materials and foliar application of micronutrients on number of leaves per plant at different days after transplanting of sweet pepper

Treatment Combinations	Number of leaves per plant at			
	45 DAT	65 DAT	85 DAT	Harvest
M_0N_0	7.02 f	15.66 f	53.23 h	113.17 f
M_0N_1	7.95 e	20.49 cd	60.44 f	117.39 e
M_0N_2	7.41 ef	19.55 de	56.99 g	115.83 e
M_1N_0	8.67 d	19.72 de	63.63 e	120.78 d
M_1N_1	9.97 bc	18.72 e	65.18 d	124.96 c
M_1N_2	9.67 c	21.44 bc	64.88 d	122.7 cd
M_2N_0	9.44 c	21.77 bc	68.11 c	128.29 b
M_2N_1	10.88 a	25.11 a	72.44 a	135.15 a
M_2N_2	10.67 ab	22.85 b	70.34 b	130.02 b
$LSD_{(0.05)}$	0.7124	1.6802	1.1922	2.3275
CV%	4.58	4.76	5.09	4.10

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

4.3 Leaf length per plant

Significant variation was observed on leaf length per plant at harvest of sweet pepper due to different mulch materials under the experiment (Table 7 and Appendix VII). At harvest, the maximum leaf length per plant (13.35 cm) was obtained from M_2 (rice straw mulch) treatment where minimum leaf length per plant (9.89 cm) was obtained from M_0 (control) treatment.

Statistically foliar application of micronutrients showed significant variation on leaf length per plant of sweet pepper (Table 8 and Appendix VII). At harvest, the maximum leaf length per plant of sweet pepper (12.44 cm) was obtained from N_1 (Zn @ 0.6% as $ZnSO_4$) treatment. On the other hand, the minimum leaf length per plant (11.27 cm) was observed from N_0 (control) treatment.

Combined effect of mulch materials and foliar application of micronutrients significantly influenced by leaf length per plant at harvest (Table 9 and Appendix VII). At harvest, the maximum leaf length per plant (13.68 cm) was achieved from M_2N_1 (rice straw mulch + Zn @ 0.6% as $ZnSO_4$) treatment combination which was statistically similar to M_2N_2 (13.42 cm) treatment combination. On the other hand the minimum leaf length per plant (9.25 cm) was observed from M_0N_0 (control) treatment combination.

4.4 Leaf breadth per plant

Non-significant variation was observed on leaf breadth per plant of sweet pepper due to different mulch materials under the experiment (Table 7 and Appendix VII). At harvest, the maximum leaf breadth per plant (7.49 cm) was obtained from M_2 (rice straw mulch) treatment where minimum leaf breadth per plant (6.81 cm) was obtained from M_0 (control) treatment.

Foliar application of micronutrients showed non-significant variation on leaf breadth per plant of sweet pepper (Table 8 and Appendix VII). At harvest, the maximum leaf breadth per plant of sweet pepper (7.45 cm) was obtained from N_1 (Zn @ 0.6% as $ZnSO_4$) treatment. On the other hand the minimum leaf breadth per plant (6.88 cm) was observed from N_0 (control) treatment.

Non-significant influence was observed on leaf breadth per plant of sweet pepper due to combined effect of mulch materials and foliar application of micronutrients (Table 9 and Appendix VII). But at harvest, the maximum leaf breadth per plant (7.81 cm) was achieved from M_2N_1 (rice straw mulch + Zn @ 0.6% as $ZnSO_4$) treatment combination. On the other hand the minimum leaf breadth per plant (6.63 cm) was observed from M_0N_0 (control) treatment combination.

Table 7. Effect of different mulch materials on leaf length and leaf breadth per plant of sweet pepper

Treatments	Leaf length per plant (cm)	Leaf breadth per plant (cm)
M_0	9.89 c	6.81
M_1	12.25 b	7.23
M_2	13.35 a	7.49
$LSD_{(0.05)}$	0.2920	0.7909^{NS}
CV%	8.81	11.12

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Table 8. Effect of foliar application of micronutrients on leaf length and leaf breadth per plant of sweet pepper

Treatments	Leaf length per plant (cm)	Leaf breadth per plant (cm)
N_0	11.27 c	6.88
N_1	12.44 a	7.45
N_2	11.79 b	7.21
$LSD_{(0.05)}$	0.2920	0.7909^{NS}
CV%	8.81	11.12

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

Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Table 9. Combined effect of mulch materials and foliar applications of micronutrients on leaf length and leaf breadth per plant of sweet pepper

Treatment Combinations	Leaf length per plant (cm)	Leaf breadth per plant (cm)
M_0N_0	9.25 f	6.63
M_0N_1	10.52 d	7.00
M_0N_2	9.93 e	6.80
M_1N_0	11.60 c	7.00
M_1N_1	13.12 b	7.53
M_1N_2	12.02 c	7.16
M_2N_0	12.96 b	7.02
M_2N_1	13.68 a	7.81
M_2N_2	13.42 ab	7.66
$LSD_{(0.05)}$	0.5057	1.3698^{NS}
CV%	8.81	11.12

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

4.5 Days to first flowering

Significant variation on days to first flowering of sweet pepper was observed due to different mulch materials (Table 10 and Appendix VII). The maximum days to first flowering of sweet pepper (52.29) was obtained from M_0 (control) treatment. On the other hand the minimum days to first flowering of sweet pepper (45.87) was obtained from M_2 (rice straw mulch) treatment. Maida *et al.* (2019) reported that the plant grown with mulch materials requires minimum days to first flowering than control.

Statistically significant difference on days to first flowering of sweet pepper was observed due to varied foliar application of micronutrients (Table 11 and Appendix VII). It was revealed that the minimum days to first flowering of sweet pepper (46.29) was obtained from N_2 (B @0.6% as H_3BO_3) treatment. On the other hand the maximum days to first flowering of sweet pepper (50.82) was observed from N_0 (control) treatment. The result of the experiment was in coincided with the findings of Salim *et al.* (2019).

Combined effect of mulch materials and foliar application of micronutrients significantly influenced by days to first flowering of sweet pepper (Table 12 and Appendix VII). From the results of the experiment revealed that the minimum days to first flowering of sweet pepper (43.17) was observed from M_2N_2 (rice straw mulch + B @ 0.6% as H_3BO_3) treatment combination. On the other hand the maximum days to first flowering of sweet pepper (55.55) was observed from M_0N_0 (control) treatment combination.

4.6 Days to 50% flowering

Days to 50% flowering of sweet pepper significantly influenced by different mulch materials (Table 10 and Appendix VII). The minimum days to 50% flowering of sweep pepper (80.44) was obtained from M_2 (rice straw mulch) treatment. On the other hand the maximum days to 50% flowering of sweet pepper (86.82) was obtained from M_0 (control) treatment. Similar result was also observed by Zerga *et al.* (2017) who reported that controlled mulch needed more time to 50% flowering where grass mulch took earlier to 50% flowering. They also revealed that the days to 50% flowering of sweet pepper increased with no mulches.

Statistically significant influence on days to 50% flowering of sweet pepper was observed due to varied foliar application of micronutrients (Table 11 and Appendix VII). It was observed that the minimum days to 50% flowering of sweet pepper (81.38) was obtained from N_2 (B @ 0.6% as H_3BO_3) treatment. On the other hand the maximum days to 50% flowering of sweet pepper (84.82) was observed from N_0 (control) treatment. Kumar *et al.* (2020) found the similar results. They reported that combined spraying of zinc and boron twice gave maximum green as well as dry yield. Spraying of zinc alone was also found to be effective in improving the growth, phenology and yield of sweet pepper.

Combined effect of mulch materials and foliar application of micronutrients significantly influenced by days to 50% flowering of sweet pepper (Table 12 and

Appendix VII). From the results of the experiment revealed that the minimum days to 50% flowering of sweet pepper (78.33) was observed from M_2N_2 (rice straw mulch + B @ 0.6% as H_3BO_3) treatment combination. On the other hand the maximum days to 50% flowering of sweet pepper (88.73) was observed from M_0N_0 (control) treatment combination.

Table 10. Effect of mulch materials on days to first and 50% flowering of sweet pepper

Treatments	**Days to flowering**	
	1st	**50%**
M_0	52.29 a	86.82 a
M_1	46.88 b	82.24 b
M_2	45.87 c	80.44 c
$LSD_{(0.05)}$	0.7140	0.7770
CV%	5.3	7.8

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Table 11. Effect of foliar application of micronutrients on days to first and 50% flowering of sweet pepper

Treatments	**Days to flowering**	
	1st	**50%**
N_0	50.82 a	84.82 a
N_1	47.93 b	83.30 b
N_2	46.29 c	81.38 c
$LSD_{(0.05)}$	0.7140	0.7770
CV%	5.3	7.8

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

Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Table 12. Combined effect of mulch materials and foliar application of micronutrients on days to first and 50% flowering of sweet pepper

Treatment Combinations	Days to first flowering	Days to 50% flowering
M_0N_0	55.55 a	88.73 a
M_0N_1	51.50 b	86.90 b
M_0N_2	49.83 c	84.83 c
M_1N_0	48.33 d	83.40 d
M_1N_1	46.44 e	82.33 de
M_1N_2	45.87 e	81.00 ef
M_2N_0	48.57 d	82.33 de
M_2N_1	45.87 e	80.67 f
M_2N_2	43.17 f	78.33 g
$LSD_{(0.05)}$	1.23	1.3459
CV%	5.30	7.80

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

4.7 Number of flowers per plant

Statistically significant variation on number of flowers per plant of sweet pepper was observed due to different mulch materials (Table 13 and Appendix VIII). The maximum number of flowers per plant (33.19) was observed from M_2 (rice straw mulch) treatment while the minimum number of flowers per plant (25.22) was obtained from M_0 (control) treatment.

Significant difference on number of flowers per plant of sweet pepper was observed due to different levels of foliar application of micronutrients (Table 14 and Appendix VIII). It was revealed that the maximum number of flowers per plant (32.25) was obtained from N_2 (B @ 0.6% as H_3BO_3) treatment. On the other hand the minimum number of flowers per plant (27.90) was observed from N_0 (control) treatment. Harris *et al.* (2018) observed the similar results. They reported that combined application of B + Mg at 100 ppm was found to be effective in enhancing plant growth, flowering and fruit yield of chilli.

Combined effect of mulch materials and micronutrients significantly influenced by number of flowers per plant of sweet pepper (Table 15 and Appendix VIII). From the results of the experiment revealed that the maximum number of flowers per plant of sweet pepper (36.13) was observed from M_2N_2 (rice straw mulch + B @ 0.6% as H_3BO_3) treatment combination. On the other hand the minimum number of flowers per plant of sweet pepper (23.92) was observed from M_0N_0 (control) treatment combination which was statistically identical to M_0N_1 (24.18) treatment combination.

4.8 Number of fruits per plant

Significant influence on number of fruits per plant of sweet pepper was observed due to different mulch materials (Table 13 and Appendix VIII). The maximum number of fruits per plant (13.59) was observed from M_2 (rice straw mulch) treatment while the minimum number of fruits per plant (7.90) was obtained from M_0 (control) treatment. Ashrafuzzaman *et al.* (2011) also observed the similar results. They revealed that mulching produced the fruits with the highest chlorophyll-a, chlorophyll-b and total chlorophyll contents and also increased the number of fruits per plant and yield.

Number of fruits per plant of sweet pepper showed significant variation due to different levels of foliar application of micronutrients (Table 14 and Appendix VIII). It was noted that the maximum number of fruits per plant (13.43) was obtained from N_2 (B @ 0.6% as H_3BO_3) treatment. On the other hand the minimum number of fruits per plant (8.96) was observed from N_0 (control) treatment. Kumar *et al.* (2020) also revealed the similar result. Thannakoon *et al.* (2020) reported that about 25% yield increment compared to control treatment when treated with micronutrients such as zinc, boron, copper etc.

Combined effect of mulch materials and micronutrients significantly influenced by number of fruits per plant of sweet pepper (Table 15 and Appendix VIII). From the results of the experiment revealed that the maximum number of fruits per plant of sweet pepper (16.92) was observed from M_2N_2 (rice straw mulch + B @ 0.6% as H_3BO_3) treatment combination. On the other hand the minimum number of fruits per plant of sweet pepper (5.83) was observed from M_0N_0 (control) treatment combination.

4.9 Length of fruit

Statistically significant variation on length of fruit of sweet pepper was observed due to varied levels of phosphorus (Table 13 and Appendix VIII). But the maximum length of fruit (9.00 cm) was observed from M_2 (rice straw mulch) treatment while the minimum length of fruit (6.81 cm) was obtained from M_0 (control) treatment.

Significant difference on length of fruit per plant of sweet pepper was observed due to varied application of micronutrients (Table 14 and Appendix VIII). It was revealed that the maximum length of fruit (8.73 cm) was obtained from N_2 (B @0.6% as H_3BO_3) treatment. On the other hand the minimum length of fruit (7.32 cm) was observed from N_0 (control) treatment.

Combined effect of mulch materials and foliar application of micronutrients significantly influenced by length of fruit per plant of sweet pepper (Table 15 and Appendix VIII). The maximum length of fruit per plant (10.10 cm) was observed from M_2N_2 (rice straw mulch + B @0.6% as H_3BO_3) treatment combination. On the other hand the minimum length of fruit per plant (6.18 cm) was observed from M_0N_0 (control) treatment combination.

4.10 Diameter of fruit

Non-significant variation on diameter of fruit per plant of sweet pepper was observed due to varied mulch materials (Table 13 and Appendix VIII). But the maximum breadth of fruit per plant (6.67 cm) was obtained from M_2 (rice straw mulch) treatment while the minimum breadth of fruit per plant (6.53 cm) was obtained from M_0 (control) treatment.

Significant difference on breadth of fruit per plant of sweet pepper was observed due to varied levels of foliar application of micronutrients (Table 14 and Appendix VIII). It was revealed that the maximum breadth of fruit per plant (6.91 cm) was obtained from N_2 (B @0.6% as H_3BO_3) treatment which was statistically similar to N_1 (6.70) treatment. On the other hand the minimum breadth of fruit per plant (6.19 cm) was observed from N_0 (control) treatment.

Combined effect of different mulch materials and foliar application of micronutrients non-significantly influenced by breadth of fruit per plant of sweet pepper (Table 15 and Appendix VIII). But the maximum breadth of fruit per plant (7.09 cm) was observed from M_2N_2 (rice straw mulch + B @0.6% as H_3BO_3) treatment combination. On the other hand the minimum breadth of fruit per plant (6.17 cm) was observed from M_0N_0 (control) treatment combination.

Table 13. Effect of mulch materials on number of flowers per plant, fruits per plant, length and diameter of fruits of sweet pepper

Treatments	Flowers per plant	Fruits per plant	Length of fruit (cm)	Diameter of fruit (cm)
M_0	25.22 c	7.90 c	6.81 c	6.53
M_1	30.61 b	11.11 b	8.43 b	6.61
M_2	33.19 a	13.59 a	9.00	6.67
$LSD_{(0.05)}$	0.4263	0.4669	0.4232	0.5837^{NS}
CV%	3.89	4.30	7.28	8.83

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Table 14. Effect of foliar application of micronutrients on number of flowers per plant, fruits per plant, length and diameter of fruits of sweet pepper

Treatments	Flowers per plant	Fruits per plant	Length of fruit (cm)	Diameter of fruit (cm)
N_0	27.90 c	8.96 c	7.32 c	6.19 b
N_1	28.88 b	10.22 b	8.19 b	6.70 ab
N_2	32.25 a	13.43 a	8.73 a	6.91 a
$LSD_{(0.05)}$	0.4263	0.4669	0.4232	0.5837
CV%	3.89	4.30	7.28	8.83

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

Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Table 15. Combined effect of mulch materials and foliar application of micronutrients on number of flowers per plant, fruits per plant, length and diameter of sweet pepper

Treatment Combinations	Flowers per plant	Fruits per plant	Length of fruit (cm)	Diameter of fruit (cm)
M_0N_0	23.92 h	5.83 g	6.18 f	6.17
M_0N_1	24.18 h	8.05 f	7.12 e	6.78
M_0N_2	27.57 g	9.83 de	7.13 e	6.88
M_1N_0	28.62 f	9.30 e	7.69 de	6.21
M_1N_1	30.17 e	10.52 d	8.62 bc	6.62
M_1N_2	33.05 b	13.53 b	8.97 b	6.75
M_2N_0	31.17 d	11.76 c	8.08 cd	6.19
M_2N_1	32.29 c	12.10 c	8.82 b	6.71
M_2N_2	36.13 a	16.92 a	10.10 a	7.09
$LSD_{(0.05)}$	0.7384	0.8088	0.7331	1.0110 ^{NS}
CV(%)	3.89	4.30	7.28	8.83

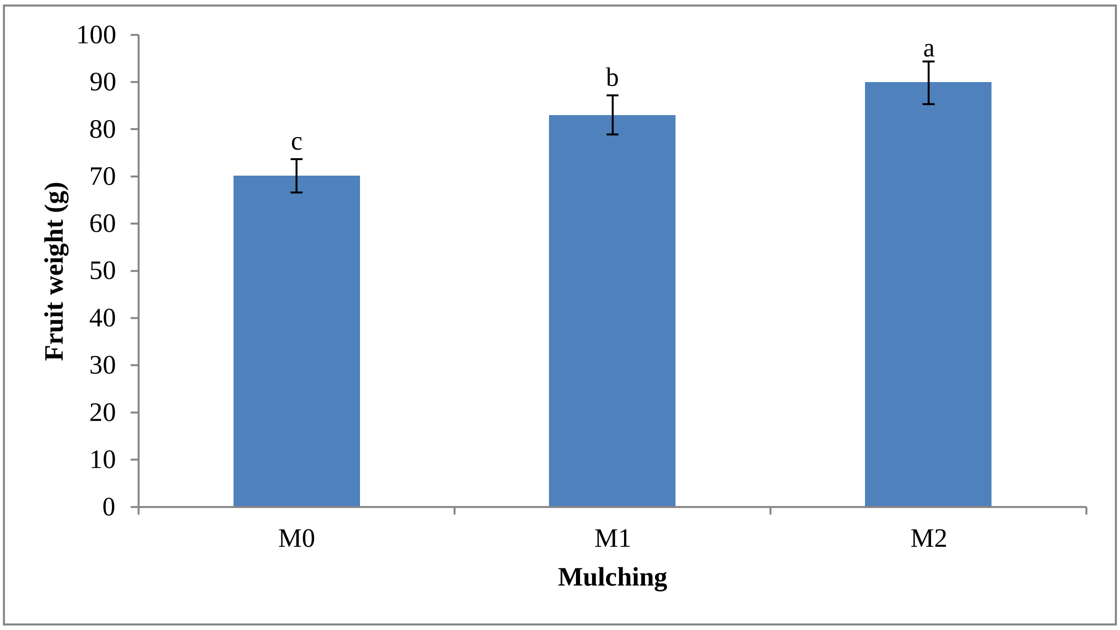
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

4.11 Individual fruit weight per plant

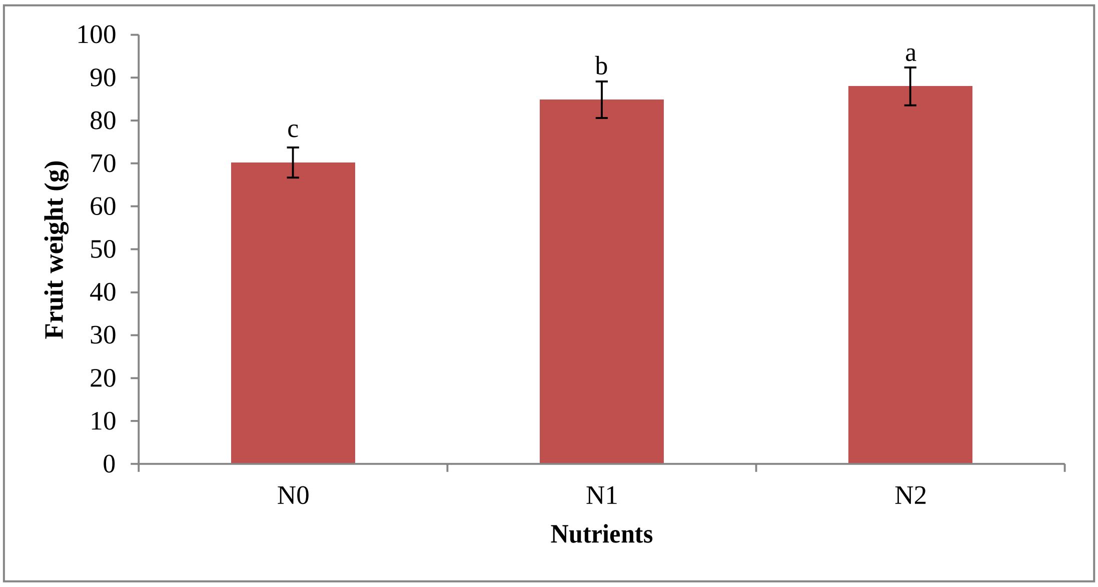
Significant variation on individual fruit weight per plant was observed due to different mulch materials (Fig. 1 and Appendix XI). From the results of the experiment showed that the maximum individual fruit weight per plant (89.85 g) was obtained from M_2 (rice straw mulch) treatment. On the other hand the minimum Individual fruit weight per plant (70.13 g) was obtained from M_0 (control) treatment. Similar result was also observed by Narayan *et al.* (2017) who reported that number of fruits, fruit length, fruit width, fruit weight and fruit yield were significantly influenced by mulch materials. Black plastic mulch (double coated) recorded the highest soil moisture retention, lowest weed density, highest number of fruits with maximum fruit weight and total fruit yield. Mulching with double coated black polythene recorded highest B:C ratio.



Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Fig. 1. Effect of mulch materials on individual fruit weight per plant of sweet pepper

Statistically significant influence on individual fruit weight per plant was observed due to different foliar application of micronutrients under the present experiment (Fig. 2 and Appendix XI). The maximum individual fruit weight per plant (87.95 g) was obtained from N_2 (B @0.6% as H_3BO_3) treatment. On the other hand the minimum individual fruit weight per plant (70.22 g) was observed from N_0 (control) treatment. The result of the experiment was in coincided with the findings of Assi *et al.* (2020). They reported that for interaction treatments, it showed excelling the spraying treatment with a mixture of iron and zinc Nano by giving it the highest values for all the yield contributing characters and yield. Khan *et al.* (2021) reported that number of fruits per plant, fruit length, fruit weight plant^{-1}, yield t/ha and 1000 seed weight were recorded maximum in the plot to which received zinc @ of 3 kg per hectares. It is concluded from the results that foliar application of boron and zinc should be used @ of 3 kg per hectares for better chilli production in the agro-climatic conditions of Swat.



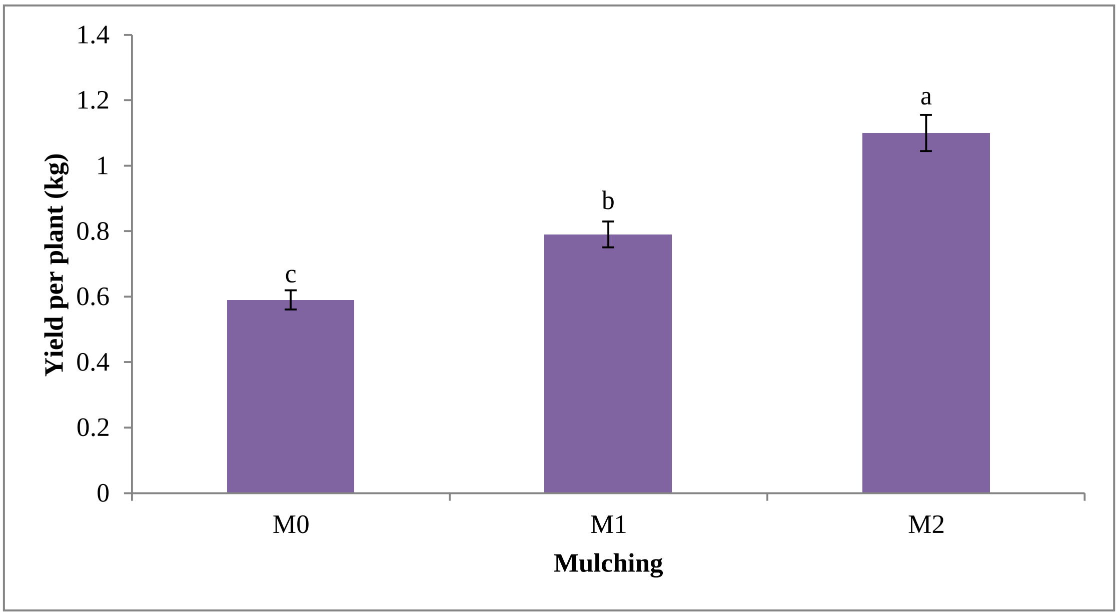
Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Fig. 2. Effect of foliar application of micronutrients on individual fruit weight per plant of sweet pepper

Combined effect of mulch materials and foliar application of micronutrients significantly influenced by individual fruit weight per plant (Table 16 and Appendix IX). From the results of the experiment revealed that the maximum individual fruit weight per plant (97.64 g) was observed from M_2N_2 (rice straw mulch + B @0.6% as H_3BO_3) treatment combination. On the other hand the minimum individual fruit weight per plant (62.66 g) was observed from M_0N_0 (control) treatment combination.

4.12 Yield per plant

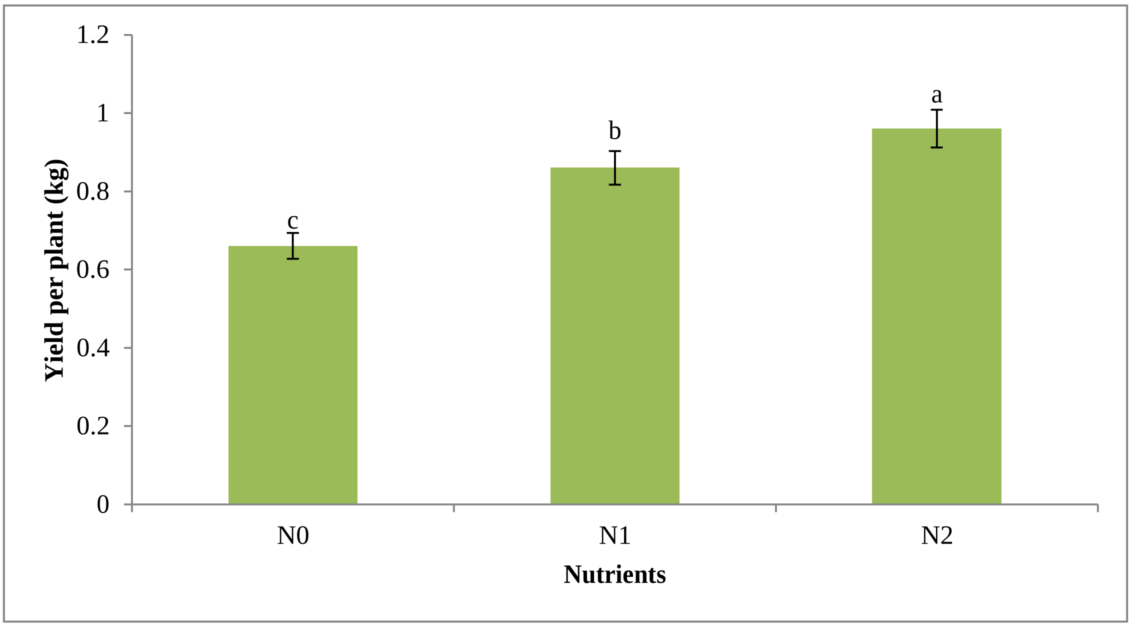
Significant variation on yield per plant was observed due to varied mulch materials (Fig. 3 and Appendix XI). From the results of the experiment showed that the maximum yield per plant (1.10 kg) was obtained from M_2 (rice straw mulch) treatment. On the other hand the minimum yield per plant (0.59 kg) was obtained from M_0 (control) treatment. The result of the experiment was in coincided with the findings of Rani *et al.* (2020) who reported that the maximum average weight of fruit, fruit yield per plant and yield per hectare was recorded maximum in case of bicolor plastic mulch as compared to paddy rice straw mulch and of control.



Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Fig. 3. Effect of mulch materials on yield per plot of sweet pepper

Statistically significant influence on yield per plant was observed due to varied foliar application of micronutrients (Fig. 4 and Appendix XI). It was observed that the maximum yield per plant (0.96 kg) was obtained from N_2 (B @0.6% as H_3BO_3) treatment. On the other hand the minimum yield per plant (0.66 kg) was observed from N_0 (control) treatment. The result of the experiment was also coincided with the findings of Singh *et al.* (2017). They revealed that T_7 (RDF + soil application of humic acid 10 kg/ha + foliar application of humic acid 0.1% + micronutrient mixture) was found statistically superior to enhance fruit weight, number of fruits per plant, and yield per plant. Nawrin *et al.* (2020) reported that micronutrient increases the yield of crops by available the soil organism. The highest fruit yield were recorded in B0.5 kg/ha + VC5 ton/ha at harvest.



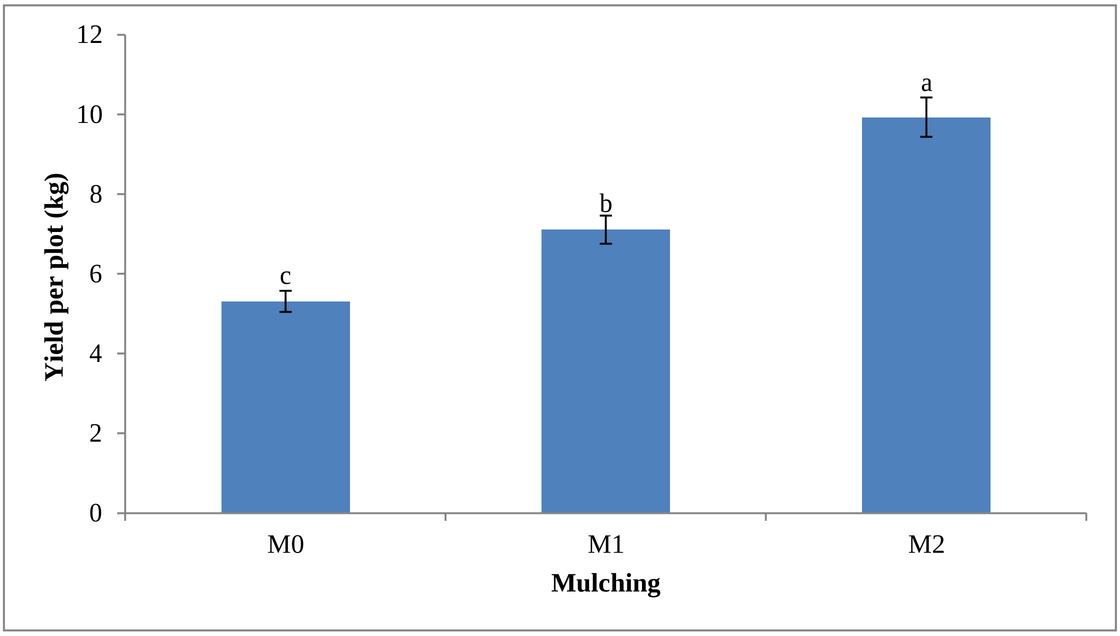
Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Fig. 4. Effect of foliar application of micronutrients on individual fruit weight per plant of sweet pepper

Yield per plant showed significant influence due to the combined effect of mulch materials and foliar application of micronutrients (Table 16 and Appendix IX). From the results of the experiment observed that the maximum yield per plant (1.26 kg) was obtained from M_2N_2 (rice straw mulch + B @0.6% as H_3BO_3) treatment combination. On the other hand the minimum yield per plant (0.49 kg) was observed from M_0N_0 (control) treatment combination.

4.13 Yield per plot

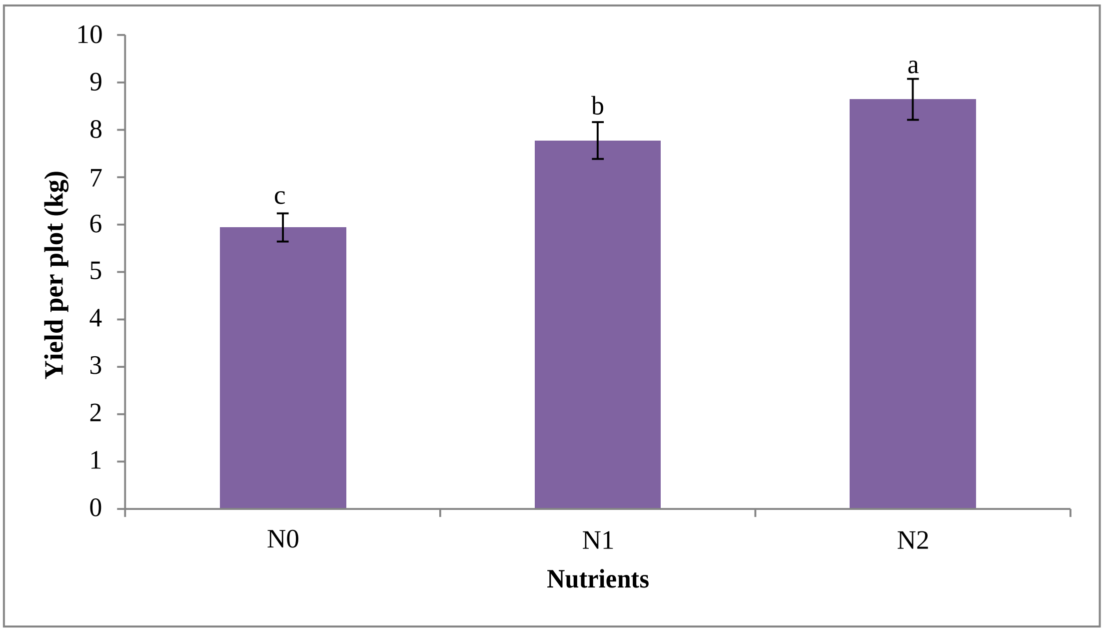
Significant variation on yield per plot was observed due to varied mulch materials (Fig. 5 and Appendix XI). The maximum yield per plot (9.93 kg) was recorded from M_2 (rice straw mulch) treatment. On the other hand the minimum yield per plot (5.31 kg) was obtained from M_0 (control) treatment. Maida *et al.* (2019) reported that the plants grown on mulch materials produced maximum fruit yield/plant, fruit yield per plot and fruit yield per hectare. Komla (2013) stated that application of rice husk mulch was the most effective treatment in increasing the weight of fruits per plant, total fruit yield and mean fruit weight per plant.



Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Fig. 5. Effect of mulch materials on yield per plot of sweet pepper

Yield per plot showed significant influence due to foliar application of micronutrients during the experimentation (Fig. 6 and Appendix XI). It was observed that the highest yield per plot (8.64 kg) was obtained from N_2 (B @0.6% as H_3BO_3) treatment. On the other hand the lowest yield per plot (5.94 kg) was observed from N_0 (control) treatment. Foliar spraying with 2000 ppm of calcium chloride plus 200 or 400 ppm of boric acid treatments obviously gave the higher values of plant height, number of branches per plant, shoot fresh and dry weights, fruit setting, fruits yield/plant and fruits yield/feddan as well as total carotenoids, vitamin C and N, P and K concentrations compared to the check treatment in both tested seasons. Shil *et al.* (2013) reported that the integrated use of zinc and boron was found superior to their single applications. The interaction effect between zinc and boron was significant in case of yield of dry chilli per plot and per hectare.



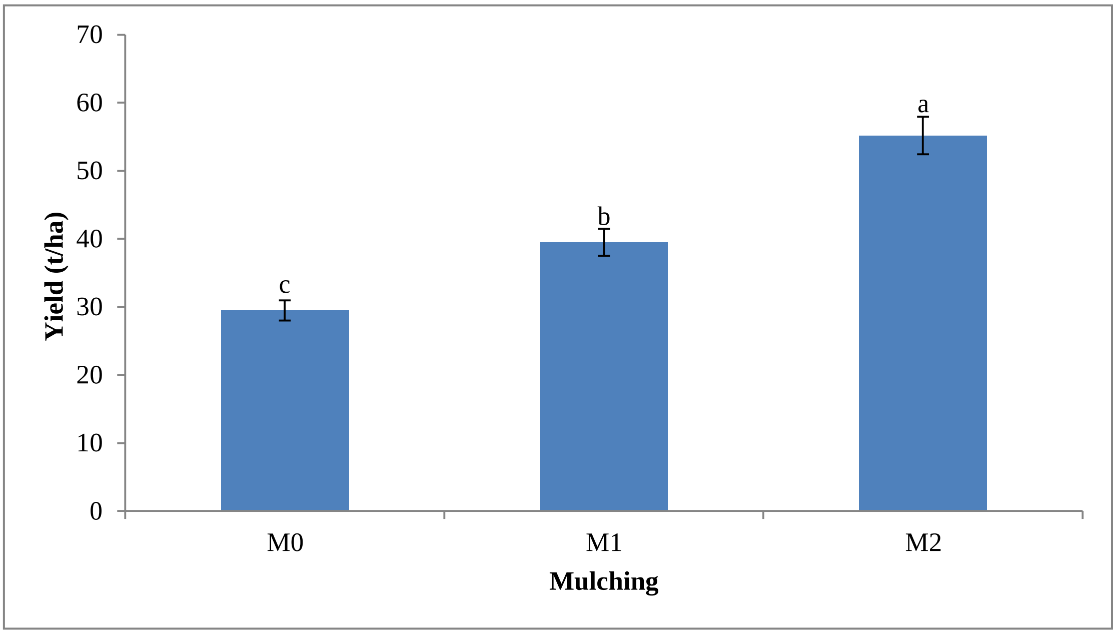
Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Fig. 6. Effect of foliar application of micronutrients on individual fruit weight per plant of sweet pepper

Combined effect of mulch materials and foliar application of micronutrients significantly influenced by yield per plot of sweet pepper (Table 16 and Appendix IX). From the results of the experiment observed that the maximum yield per plot (11.34 kg) was obtained from M_2N_2 (rice straw mulch + B @0.6% as H_3BO_3) treatment combination. On the other hand the minimum yield per plot (4.41 kg) was observed from M_0N_0 (control) treatment combination.

4.14 Yield per hectare

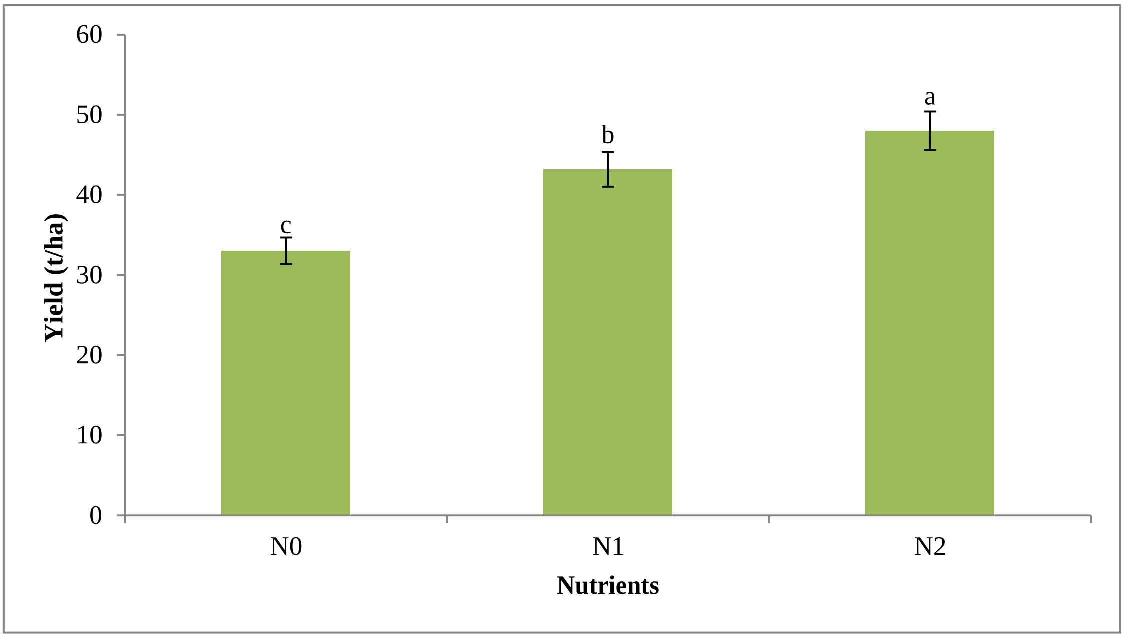
Significant variation was observed on yield per hectare of sweet pepper due to different mulch materials under the present study (Fig. 7 and Appendix XI). From the results of the experiment showed that the maximum yield per hectare (55.17 t) was obtained from M_2 (rice straw mulch) treatment. On the other hand the minimum yield per hectare (29.50 t) was obtained from M_0 (control) treatment. The result was in coincided with the findings of Yasmin *et al.* (2020) who reported that rice straw mulch treatment produced highest green chilli yield which was 26.94 % increase over no mulch treatment.



Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Fig. 7. Effect of mulch materials on yield per hectare of sweet pepper

Statistically significant influence on yield per hectare was observed due to different levels of foliar application of micronutrients (Fig. 8 and Appendix XI). It was revealed that the minimum yield per hectare (48.00 t) was revealed from N_2 (B @0.6% as H_3BO_3) treatment. On the other hand the minimum yield per hectare (33.00 t) was obtained from N_0 (control) treatment. The result of the experiment was also coincided with the findings of Ashraf *et al.* (2020) who reported that maximum fruit yield per plant, maximum fruit yield per hectare, highest value of 100 seeds weight were obtained by foliar application of micronutrients., Hence, it was concluded that foliar application of zinc and boron increased yield characters up to maximum and this dose can be recommended to farmers to get more yield and ultimately increase their profit.



Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Fig. 8. Effect of foliar application of micronutrients on yield per hectare of sweet pepper

Combined effect of mulch materials and foliar application of micronutrients significantly influenced by yield per hectare of sweet pepper (Table 16 and Appendix IX). From the results of the experiment revealed that the maximum yield per hectare (63.00 t) was observed from M_2N_2 (rice straw mulch + B @0.6% as H_3BO_3) treatment combination. On the other hand the minimum yield per hectare (24.50 t) was obtained from M_0N_0 (control) treatment combination.

Maximum yield was obtained from rice straw mulch with foliar application of boron (0.6%). Using of straw with cowdung, poultry manure, mushroom spent substrate as well as recommended NPK reduces wilt incidence (Ramnesh and Manjunath, 2002). The recorded temperature was varied from 17°C-33°C from December to April, 2021 (temperature was recorded by thermo-hygrometer in experiment field of SAU horticulture farm). In generally, black polythene increases soil temperature to 4-5° whereas straw of wheat or paddy increases to 2-3°. Suwon and Judah (1985) observed that soil temperature increased with the use of plastic mulch. However, Combination of environmental temperature and soil temperature favored plant stress and lowered the resistance against diseases. Another way, temperature of straw was constantly suitable for proper growth and development of vegetative and reproductive stage of plant.

The yield increase under rice straw mulch could be due to their ability to reduce soil temperature fluctuation, to add organic matter by decomposition, increased water holding capacity, smothering weed population, which led to favorable condition for plant growth and development. The positive influence of organic mulch materials on yield was also reported by (Uniyal and Mishra, 2003) in potato. Black plastic alters the plants growth by enhancement in soil temperature; so that plants can increase growth, profuse flowering and fruiting, resulting in earlier and high yields as compared to control. Similar kind of observation was also reported by (Singh *et al.*, 2005) in tomato and (Nimah, 2007) in cucumber.

Table 16. Combined effect of mulch materials and foliar application of micronutrients on individual fruit weight, yield per plant, yield per plot and yield per hectare of sweet pepper

Treatment Combinations	Individual fruit weight (g)	Yield per plant (kg)	Yield per plot (kg)	Yield per hectare (t)
M_0N_0	62.66 g	0.49 h	4.41 h	24.50 i
M_0N_1	72.90 ef	0.62 fg	5.58 fg	31.00 g
M_0N_2	74.82 de	0.66 f	5.94 f	33.00 f
M_1N_0	70.27 f	0.58 g	5.22 g	29.00 h
M_1N_1	87.41 c	0.83 e	7.47 e	41.50 e
M_1N_2	91.39 b	0.96 c	8.64 c	48.00 c
M_2N_0	77.73 d	0.91 d	8.19 d	45.50 d
M_2N_1	94.18 b	1.14 b	10.26 b	57.00 b
M_2N_2	97.64 a	1.26 a	11.34 a	63.00 a
$LSD_{(0.05)}$	3.1588	0.0425	0.4248	1.8014
CV(%)	2.25	2.97	3.29	2.51

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

4.15 Total soluble solids

Total soluble solids showed non-significant variation on sweet pepper influenced by different mulch materials (Table 17 and Appendix X). But the maximum amount of total soluble solids (5.90 °brix) was obtained from M_1 (Black polyethylene mulch) treatment. The minimum amount of total soluble solids (5.68 °brix) was found from M_0 (control) treatment. The results of the experiment was in agreement with the findings of Sageer *et al.* (2015) who reported that black polyethylene mulches increases the TSS, total sugar contents, total carotenoids and vitamin C contents in sponge gourd.

Total soluble solids showed significant variation on sweet pepper influenced by foliar application of micronutrients (Table 18 Appendix X). Results showed that the maximum amount of total soluble solids (6.50 °brix) was obtained from N_2 (B @0.6% as H_3BO_3) treatment. On the other hand the minimum amount of total soluble solids (5.17 °brix) was found from N_0 (control) treatment.

Significant variation on total soluble solids of sweet pepper was observed due to combined effect of mulch materials and foliar application of micronutrients (Table 19 and Appendix X). Results noted that the maximum amount of total soluble solids (6.80 °brix) was found from M_2N_2 (rice straw mulch + B @0.6% as H_3BO_3) treatment combination which was statistically similar to M_1N_2 (6.50 °brix) treatment combination. On the other hand, the minimum amount of total soluble solids (4.90 °brix) was obtained from M_0G_0 (control) treatment combination which was statistically similar to M_1N_0 (5.20 °brix) treatment combination.

4.16 Vitamin C contents

Non-significant variation on vitamin C contents was observed on sweet pepper influenced by different mulch materials (Table 17 and Appendix X). But the maximum amount of vitamin C contents (134.88 mg/100 g) was obtained from M_2 (rice straw mulch) treatment. On the other hand the minimum amount of vitamin C contents (133.93 mg/100 g) was found from M_0 (control) treatment. Roudan and Abbdosi (2015) reported that mulches helps to increases the TSS, total sugars and vitamin C contents in cucumber.

Marked difference was observed on vitamin C contents influenced by foliar application of different micronutrients (Table 18 and Appendix X). Results showed that the maximum amount of vitamin C contents (138.97 mg/100 g) was obtained from N_2 (B @0.6% as H_3BO_3) treatment. The minimum amount of vitamin C contents (130.28 mg/100 g) was found from N_0 (control) treatment.

Significant variation on vitamin C contents of sweet pepper was observed due to combined effect of mulch materials and foliar application of micronutrients (Table 19 and Appendix X). The maximum amount of vitamin C contents (140.40 mg/100 g) was found from M_2N_2 (rice straw mulch + B @0.6% as H_3BO_3) treatment combination while the minimum amount of vitamin C contents (128.91 mg/100 g) was obtained from M_0G_0 (control) treatment combination.

Table 17. Effect of mulch materials on total soluble solids and vitamin C contents of sweet pepper

Treatments	Total soluble solids (°brix)	Vitamin C contents (mg/100 g)
M_0	5.68	133.93
M_1	5.90	134.35
M_2	5.87	134.88
$LSD_{(0.05)}$	0.2788^{NS}	1.1227^{NS}
CV%	7.65	5.42

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

Table 18. Effect of foliar application of micronutrients on total soluble solids and vitamin C contents of sweet pepper

Treatments	Total soluble solids (°brix)	Vitamin C contents (mg/100 g)
N_0	5.17 c	130.28 c
N_1	5.78 b	133.91 b
N_2	6.50 a	138.97 a
$LSD_{(0.05)}$	0.2788	1.1227
CV%	7.65	5.42

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

Here, N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Table 19. Combined effect of mulch materials and foliar application of micronutrients on total soluble solids and vitamin C contents of sweet pepper

Treatment Combinations	Total soluble solids (°brix)	Vitamin C contents (mg/100 g)
M_0N_0	4.90 e	128.91 e
M_0N_1	5.93 c	134.71 c
M_0N_2	6.20 bc	138.16 b
M_1N_0	5.20 de	130.90 d
M_1N_1	6.00 c	133.81 c
M_1N_2	6.50 ab	138.35 b
M_2N_0	5.43 d	131.04 d
M_2N_1	5.40 d	133.21 c
M_2N_2	6.80 a	140.40 a
$LSD_{(0.05)}$	0.4829	1.9446
CV%	7.65	5.42

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

4.17 Economic analysis

Input costs for land preparation, fertilizer, irrigation and manpower required for all the operations from seed sowing to harvesting of sweet pepper were recorded as per experimental plot and converted into cost per hectare. Price of sweet pepper was considered as per market rate (30,000 Tk. per ton). The economic analysis presented under the following headings-

4.17.1 Gross return

The combination of mulch materials and foliar application of micronutrients showed different value in terms of gross return under the study (Table 20). The highest gross return (Tk. 1,890,000) was obtained from the treatment combination M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) treatment combination and the second highest gross return (Tk. 1,710,000) was found in M_2N_1. The lowest gross return (Tk. 735,000) was obtained from M_0N_0 (control) treatment combination (Table 20).

4.17.2 Net return

Net return was calculated by the difference between gross return and total cost of production. Different value of net return was found from different mulch materials and foliar application of micronutrients. Highest net return Tk. 1,458,860 was obtained from M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) treatment combination and second highest Tk. 1,306,085 was obtained from treatment combination M_2N_1. On the other hand lowest net return Tk. 377,364 was obtained from M_0N_0 (control) treatment combination (Table 20).

4.17.3 Benefit cost ratio

Application of different mulch materials and foliar application of micronutrients exerted the highest benefit cost ratio (4.67) was noted from the combination of M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) treatment combination and the second highest benefit cost ratio (4.23) was estimated from the combination of M_2N_1 and the lowest benefit cost ratio (2.05) was obtained from M_0N_0 (control) treatment combination (Table 20). From economic point of view, it is apparent from the above results that the combination of M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) was more profitable treatment combination than rest of the treatment combinations. Benefit Cost Ratio was calculated by the following-

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

Table 20. Cost and return of sweet pepper cultivation as influenced by different mulch materials and foliar application of micronutrients

Treatments	Yield (t/ha)	Gross return (Tk./ha)	Total cost of production (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio (BCR)
M_0N_0	24.50	735000	357636	377364	**2.05**
M_0N_1	31.00	930000	358735	571265	**2.59**
M_0N_2	33.00	990000	358990	631010	**2.76**
M_1N_0	29.00	870000	414073	455927	**2.10**
M_1N_1	41.50	1245000	417773	827227	**2.98**
M_1N_2	48.00	1440000	418000	1022000	**3.44**
M_2N_0	45.50	1365000	402786	962214	**3.39**
M_2N_1	57.00	1710000	403915	1306085	**4.23**
M_2N_2	63.00	1890000	404140	1458860	**4.67**

Selling price= 30,000 Tk. per ton

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

CHAPTER IV

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the "Horticulture Farm" of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November 2020 to April 2021 to study the effect of different mulch materials and foliar application of micronutrients on growth and yield of sweet pepper under net house. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Madhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors. Factor A: Three mulch materials *viz.*, M_0= No mulch (control), M_1= Black polyethylene mulch and M_2= Rice straw mulch and Factor B: Three levels foliar application of micronutrients *viz.*, N_0= no micronutrients (control), N_1= Zn @0.6% as $ZnSO_4$ and N_2= B @0.6% as H_3BO_3. There were 9 treatment combinations. The total numbers of unit plots were 27. The size of unit plot was 1.8 m^2 (1.5 m × 1.2 m). Data on different growth, yield contributing characters and yield were recorded to find out the best mulch materials and optimum levels of foliar applications of micronutrients for the potential yield of sweet pepper under net house.

Data revealed that in case of different mulch materials, at harvest, the tallest plant (83.02 cm) was observed from M_1 (Black polyethylene mulch) treatment and the shortest plant (68.10 cm) was obtained from M_0 (control) treatment. The maximum number of leaves per plant (131.15), leaf length (13.35 cm), flowers per plant (33.19), fruits per plant (13.59), fruit length (9.00 cm), individual weight of fruit per plant (89.85 g), yield per plant (1.10 kg), yield per plot (9.93 kg) and yield per hectare (55.17 t) were obtained from M_2 (Rice straw mulch) treatment. On the other hand, at harvest, the minimum number of leaves per plant (115.46), leaf length (9.89 cm), flowers per plant (25.22), fruits per plant (7.90), fruit length (6.81 cm), individual weight of fruit per plant (70.13 g), yield per plant (0.59 kg), yield per plot (5.31 kg) and yield per hectare (29.50 t) were obtained from M_0 (control) treatment. But, maximum days to 1^{st} flowering (52.29) and days to 50% flowering (86.82) were obtained from M_0 (control) treatment where minimum days to 1^{st} flowering (45.87) and days to 50% flowering (80.44) were obtained from M_2 (Rice straw mulch) treatment.

Foliar application of different micronutrients significantly influence the growth, yield contributing characters and yield of sweet pepper. Data revealed that in case of application of micronutrients, at harvest, the tallest plant (76.99 cm), maximum number of leaves per plant (125.83) was noted from N_1 (Zn @0.6% as $ZnSO_4$) treatment. On the other hand, the shortest plant (71.25 cm), minimum number of leaves per plant (120.74) was noted from N_0 (control) treatment. The maximum number of flowers per plant (32.25), fruits per plant (13.43), fruit length (8.73 cm), fruit diameter (6.91 cm), individual weight of fruit per plant (87.95 g), yield per plant (0.96 kg), yield per plot (8.64 kg), yield per hectare (48.00 t), total soluble solids (6.50 °brix) and vitamin C content (138.97 mg/100 g) were obtained from N_2 (B @0.6% as H_3BO_3) treatment. On the other hand, at harvest, the minimum number of flowers per plant (27.90), fruits per plant (8.96), fruit length (7.32 cm), fruit diameter (6.19 cm), individual weight of fruit per plant (70.22 g), yield per plant (0.66 kg), yield per plot (5.94 kg), yield per hectare (33.00 t), total soluble solids (5.17 °brix) and vitamin C content (130.28 mg/100 g) were obtained from N_0 (control) treatment. But, maximum days to 1st flowering (50.82) and days to 50% flowering (84.82) were obtained from N_0 (control) treatment where minimum days to 1st flowering (46.29) and days to 50% flowering (81.38) were obtained from N_2 (B @0.6% as H_3BO_3) treatment.

Combined effect of different mulch materials and foliar application of micronutrients significantly influenced by the growth, yield contributing characters and yield of sweet pepper. Data revealed that at harvest, the tallest plant at harvest (85.73 cm) was observed from the treatment combination of M_1N_1 (Black polyethylene mulch + Zn @ 0.6% as $ZnSO_4$) and the shortest plant (61.78 cm) was observed from M_0N_0 (control) treatment combination. The maximum number of leaves per plant (135.15) was noted from M_2N_1 (Straw mulch + Zn @0.6% as $ZnSO_4$)) treatment combination. On the other hand, minimum number of leaves per plant (113.17) was observed from M_0N_0 (control) treatment combination. The maximum leaf length (13.68 cm), number of flowers per plant (36.13), fruits per plant (16.92), fruit length (10.10 cm), individual weight of fruit per plant (97.64 g), yield per plant (1.26 kg), yield per plot (11.34 kg), yield per hectare (63.00 t), total soluble solids (6.80 °brix) and vitamin C content (140.40 mg/100 g) were obtained from M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) treatment combination. On the other hand, at harvest, the minimum leaf length (9.25 cm), number of flowers per plant (23.92), fruits per plant (5.83), fruit length (6.18 cm), individual weight of fruit per plant (62.66 g), yield per plant (0.49 kg), yield per plot (4.41 kg), yield per hectare (24.50 t), total soluble solids (4.90 °brix) and vitamin C content (128.91 mg/100 g) were obtained from M_0N_0 (control) treatment combinations. But, maximum days to 1st flowering (55.55) and days to 50% flowering (88.73) were obtained from M_0N_0 (control) treatment combination where minimum days to 1st flowering (43.17) and days to 50% flowering (78.33) were obtained from M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) treatment combinations.

The highest gross return (Tk. 1,890,000) was obtained from M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) treatment combination and the second highest gross return (Tk. 1,710,000) was found in M_2N_1 (Rice straw mulch + Zn @0.6% as $ZnSO_4$) treatment combinations. The lowest gross return (Tk. 735,000) was obtained from M_0N_0 (control) treatment combination. Highest net return Tk. 1,458,860 was obtained from M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) treatment combination and second highest Tk. 1,306,085 was obtained from M_2N_1 treatment combination. On the other hand lowest net return Tk. 377,364 was obtained from M_0N_0 (control) treatment combination. The highest benefit cost ratio (4.67) was noted from M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) treatment combination and the second highest benefit cost ratio (4.23) was estimated from M_2N_1 treatment combination and the lowest benefit cost ratio (2.05) was obtained from M_0N_0 (control) treatment combination.

CONCLUSION

- This study revealed that different mulch materials and foliar application of micronutrients have a positive effect on growth and yield of sweet pepper.
- In case of yield of sweet pepper, the combination of mulch materials M_2 (Straw mulch) along with foliar application of micronutrients N_2 (B @0.6% as H_3BO_3) were given the better performance of all the yield contributing parameters, yield (63.00 t ha^{-1}) and quality of sweet pepper than the other treatment combinations.
- In the consideration value for money concept, the treatment combination M_2N_2 (Rice straw mulch + B @0.6% as H_3BO_3) was more suitable as the highest benefit cost ratio (8.09) than the other treatment combinations. So, it can be concluded that farmers will be benefitted by applying rice straw mulch with three times foliar application of B @ 0.6% in capsicum production. But it can be repeated in different agro ecological zones of Bangladesh for better yield and consideration value for money concept.

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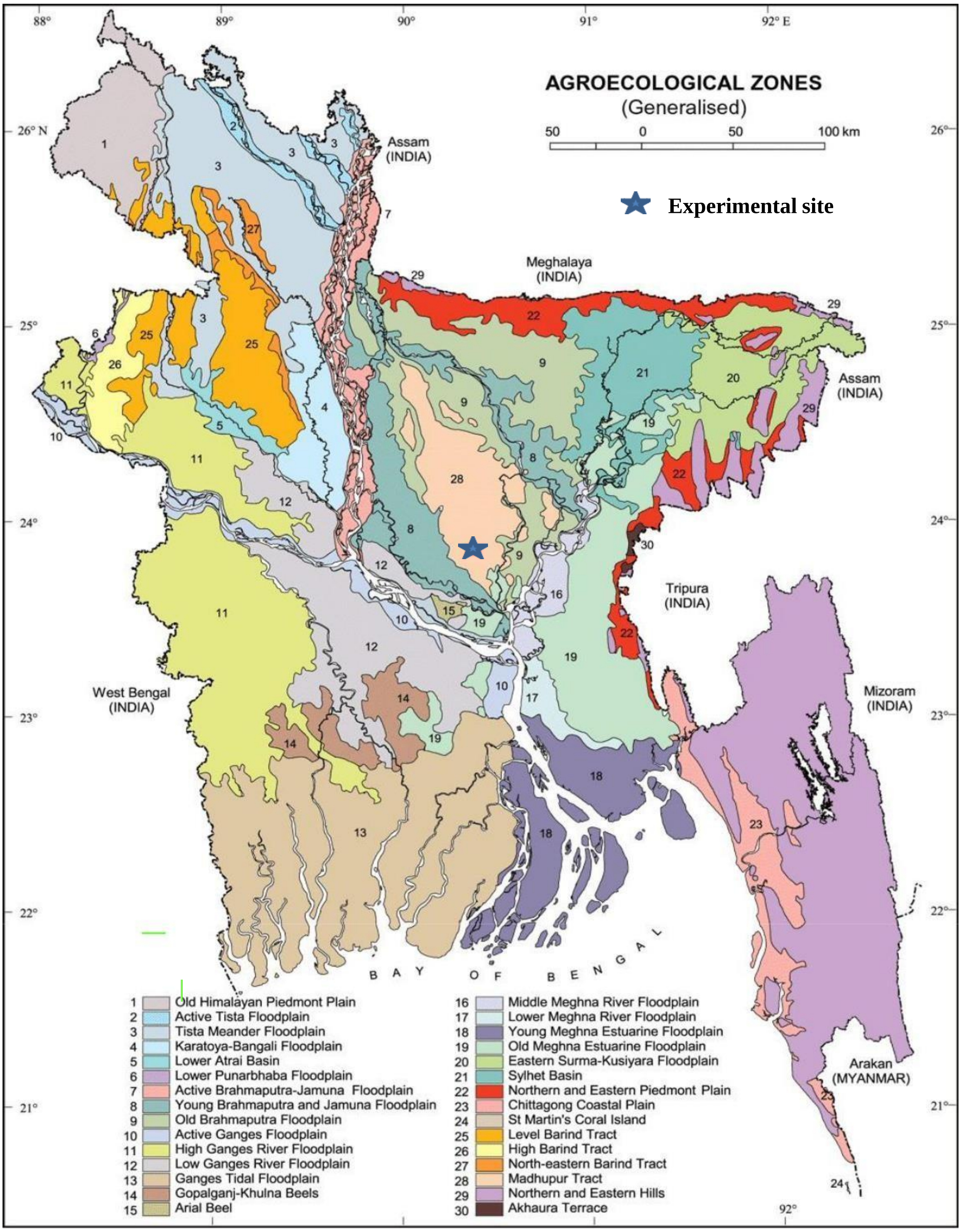
APPENDICES

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2020 to April 2021

Month and year	RH (%)	Air temperature (°C)			Rainfall (mm)
		Max.	*Min.*	*Mean*	
November, 2020	56.25	28.70	8.62	18.66	14.5
December, 2020	51.75	26.50	9.25	17.87	12.0
January, 2021	46.20	23.70	11.55	17.62	0.0
February, 2021	37.95	22.85	14.15	18.50	0.0
March, 2021	35.75	21.55	15.25	18.40	0.0
April, 2021	34.50	30.50	18.50	24.50	90

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

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

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

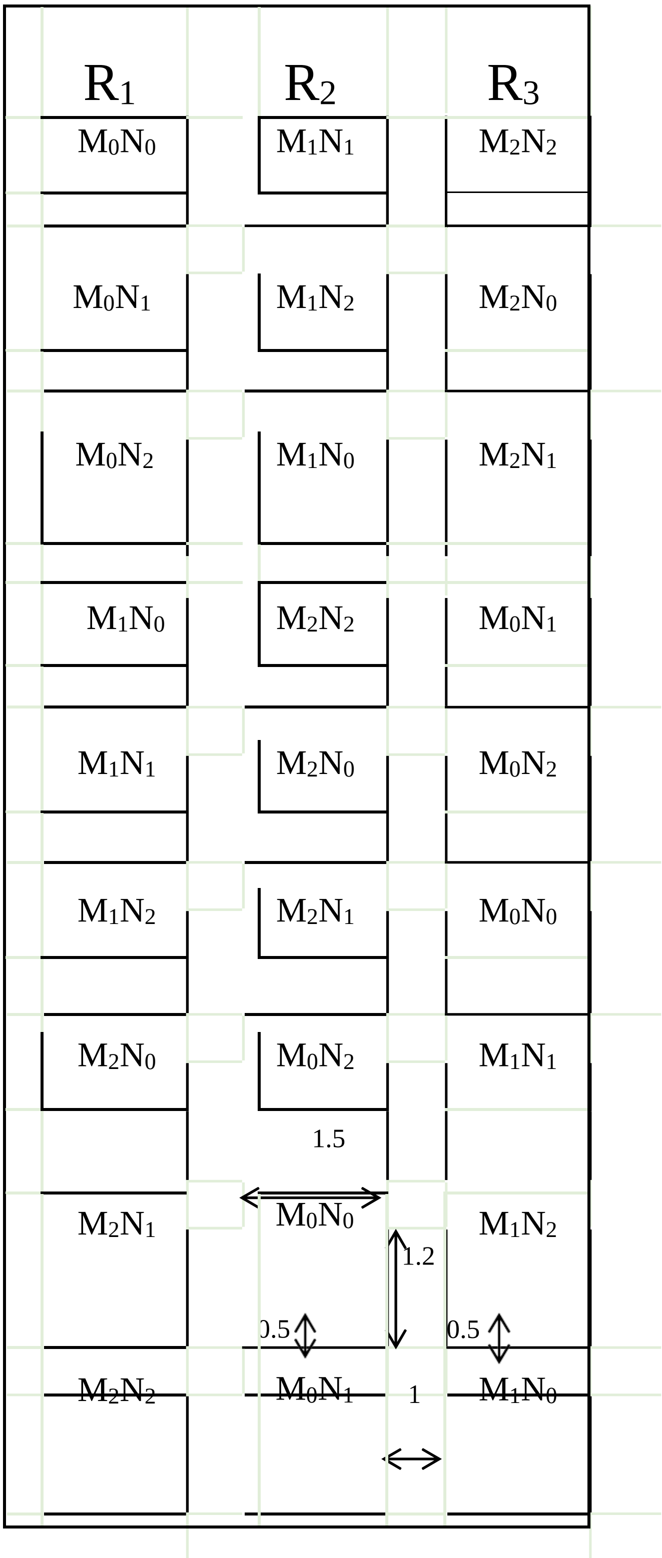
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

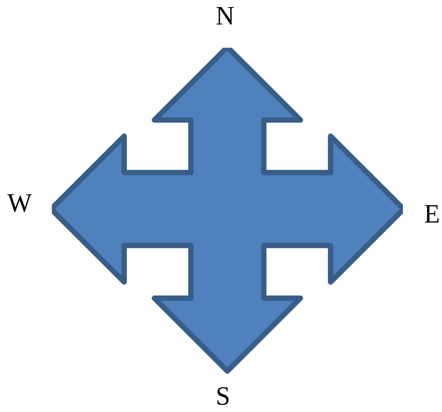
Characteristics	Value
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam
pH	6.2
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experimental field



LEGENDS



Plot size: 1.5 m × 1.2 m

Factor A: Different Mulch (3)

M_0= No mulch (control)

M_1= Black polyethylene mulch

M_2= Rice straw mulch

Factor B: Micronutrients (3)

N_0= Control

N_1= Zn @0.6% as $ZnSO_4$

N_2= B @0.6% as H_3BO_3

Appendix V. Mean square values of plant height at different days after transplanting of sweet pepper

Source of variation	Degrees of freedom	Mean square of plant height at			
		45 DAT	65 DAT	85 DAT	Harvest
Replication	2	0.10029	0.2257	1.626	0.256
Mulching (A)	2	6.17045**	48.4172**	438.577**	516.714**
Nutrients (B)	2	1.44018**	14.6098**	62.873**	86.657**
Interaction (AxB)	4	0.57861**	4.2238**	3.507**	17.170**
Error	16	0.16668	0.9844	1.770	2.861

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VI. Mean square values of number of leaves plant^{-1} at different days after transplanting of sweet pepper

Source of variation	Degrees of freedom	Mean square of number of leaves at			
		45 DAT	65 DAT	85 DAT	Harvest
Replication	2	0.2213	0.0662	0.174	0.255
Mulching (A)	2	19.3899**	51.8349**	407.375**	554.538**
Nutrients (B)	2	3.5622**	16.0351**	43.067**	58.750**
Interaction (AxB)	4	0.1443**	9.0160**	6.041**	3.099**
Error	16	0.1664	1.0710	0.522	2.039

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VII. Mean square values of leaf length plant^{-1}, leaf breadth plant^{-1}, days to first flowering and days to 50% flowering of sweet pepper growing during experimentation

Source of variation	Degrees of freedom	Mean square values of			
		Leaf length	Leaf breadth	Days to first flowering	Days to 50% flowering
Replication	2	0.96371	1.49963	0.649	0.7248
Mulching (A)	2	1.44863*	1.07168 NS	107.51**	97.3081**
Nutrients (B)	2	1.00074*	0.71923 NS	47.29**	26.6359**
Interaction (AxB)	4	0.07869*	0.06699 NS	2.769**	0.617**
Error	16	1.43983	0.52995	0.504	0.6019

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VIII. Mean square values of number of flowers plant^{-1}, number of fruits plant^{-1}, fruit length and fruit diameter of sweet pepper growing during experimentation

Source of variation	Degrees of freedom	Mean square values of			
		No. of flowers per plant	No. of fruits per plant	Fruit length	Fruit diameter
Replication	2	0.2998	3.6133	0.43978	0.31103
Mulching (A)	2	18.1199**	73.2532**	0.54340**	0.04164 NS
Nutrients (B)	2	32.0534**	47.6554**	1.28593**	1.22770 NS
Interaction (AxB)	4	1.9442**	1.8002**	0.00799**	0.03368 NS
Error	16	0.5967	0.2183	0.37890	0.35193

* significant at 5% level of significance
** significant at 1% level of significance

Appendix IX. Mean square values of individual fruit weight, yield per plant, yield per plot and yield per hectare of sweet pepper growing during experimentation

Source of variation	Degrees of freedom	Mean square values of			
		Individual fruit weight	Yield per plant	Yield per plot	Yield per hectare
Replication	2	0.412	0.03868	0.9280	40.24
Mulching (A)	2	903.369**	0.60253**	48.8052**	1506.33**
Nutrients (B)	2	806.309**	0.21103**	17.0937**	527.58**
Interaction (A × B)	4	19.589**	0.00973**	0.7884**	24.33**
Error	16	3.330	0.00060	0.0602	1.08

* significant at 5% level of significance
** significant at 1% level of significance

Appendix X. Mean square values of total soluble solids and vitamin C content of sweet pepper growing under the experiment

Sources of variation	Degrees of freedom	Mean square values of	
		Total soluble solids	Vitamin C content
Replication	2	2.20259	3.708
Mulching (A)	2	0.34481^{NS}	2.069^{NS}
Nutrients (B)	2	1.79148**	171.346**
Interaction (A × B)	4	0.36481**	4.259**
Error	16	0.90009	1.262

* significant at 5% level of significance
** significant at 1% level of significance

Appendix XI. Effect of mulch materials and foliar application of micronutrients on yield contributing characters and yield of sweet pepper

Treatment	Individual fruit weight per plant (g)	Yield per plant (kg)	Yield per plot (kg)	Yield per hectare (t)
Effect of mulch materials				
M_0	70.13 c	0.59 c	5.31 c	29.50 c
M_1	83.02 b	0.79 b	7.11 b	39.50 b
M_2	89.85 a	1.10 a	9.93 a	55.17 a
$LSD_{(0.05)}$	1.8237	0.0245	0.2453	1.0401
CV%	2.25	2.97	3.29	2.51
Effect of micronutrients				
N_0	70.22 c	0.66 c	5.94 c	33.00 c
N_1	84.83 b	0.86 b	7.77 b	43.17 b
N_2	87.95 a	0.96 a	8.64 a	48.00 a
$LSD_{(0.05)}$	1.8237	0.0245	0.2453	1.0401
CV%	2.25	2.97	3.29	2.51

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

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

Appendix XII. Production cost of sweet pepper per hectare

A) Material cost (Tk./ha)

Treatment combinations	Capsicum Seed cost	Fertilizers and manures						Sub Total
		Urea	TSP	MoP	$ZnSO_4$	Borax	Cowdung	1 (A)
M_0N_0	20000	5500	7260	3750	-	-	50000	86510
M_0N_1	20000	5500	7260	3750	1000	-	50000	87510
M_0N_2	20000	5500	7260	3750	-	1200	50000	87710
M_1N_0	20000	5500	7260	3750	-	-	50000	86510
M_1N_1	20000	5500	7260	3750	1000	-	50000	87510
M_1N_2	20000	5500	7260	3750	-	1200	50000	87710
M_2N_0	20000	5500	7260	3750	-	-	50000	86510
M_2N_1	20000	5500	7260	3750	1000	-	50000	87510
M_2N_2	20000	5500	7260	3750	-	1200	50000	87710

Labor cost: 300 Tk. per person
Capsicum seed @ Tk. 20000
Urea @ Tk. 22 kg^{-1}
TSP @ Tk. 22 kg^{-1}
MoP @ Tk. 15 kg^{-1}
$ZnSO_4$ @ Tk. 200 kg^{-1}
Borax @ Tk. 240 kg^{-1}
Cowdung @ Tk. 5000 t^{-1}

B) Non-material cost (Tk./ha)

Labor cost: 300 Tk. per person

Treatment combinations	Land preparation	Net cost	Seed sowing and transplanting	Mulching cost	Intercultural operation	Harvesting	Sub total	Total input cost 1 (A) + 1 (B)
M_0N_0	30000	50000	15000	-	18000	24000	137000	223510
M_0N_1	30000	50000	15000	-	18000	24000	137000	224510
M_0N_2	30000	50000	15000	-	18000	24000	137000	224710
M_1N_0	30000	50000	15000	50000	18000	24000	187000	273510
M_1N_1	30000	50000	15000	50000	18000	24000	187000	274510
M_1N_2	30000	50000	15000	50000	18000	24000	187000	274710
M_2N_0	30000	50000	15000	40000	18000	24000	177000	263510
M_2N_1	30000	50000	15000	40000	18000	24000	177000	264510
M_2N_2	30000	50000	15000	40000	18000	24000	177000	264710

B. Overhead cost and total cost of production (Tk./ha)

Treatment combinations	Cost of lease of land for 6 months	Miscellaneous cost (5% of input cost)	Interest on running capital for 6 months (15% of the total input cost)	Total	Total cost of production (input cost + interest on running capital, Tk./ha)
M_0N_0	98000	11175	24951	134126	357636
M_0N_1	98000	11225	25030	134255	358735
M_0N_2	98000	11235	25045	134280	358990
M_1N_0	98000	13675	28888	140563	414073
M_1N_1	98000	13725	28967	143267	417773
M_1N_2	98000	13735	28983	143293	418000
M_2N_0	98000	13175	28101	139276	402786
M_2N_1	98000	13225	28180	139405	403915
M_2N_2	98000	13235	28195	139430	404140

Labor cost: 300 Tk. per person

Here, M_0= Control, M_1= Black polyethylene mulch and M_2= Rice straw mulch

N_0= control, N_1= Zn @ 0.6% as $ZnSO_4$ and N_2= B @ 0.6% as H_3BO_3

SOME PICTORIAL VIEW DURING EXPERIMENTATION

Plate 1. Photograph of experimental plot

Plate 2. Photograph of straw mulches plot

Plate 3. Photograph of black polyethylene mulches plot

Plate 4. Photograph of controlled (no mulch) plot treating with insecticides

Plate 5. Photograph of harvested fruits (Treatment wise)

Plate 6. Photograph of harvested fruits