GROWTH AND YIELD OF RED CABBAGE INFLUENCED BY ZINC UNDER DIFFERENT MULCH PRACTICES

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CERTIFICATE

This is to certify that the thesis entitled **"GROWTH AND YIELD OF RED CABBAGE INFLUENCED BY ZINC UNDER DIFFERENT MULCH PRACTICES"** submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **HORTICULTURE**, embodies the result of a piece of bonafide research work carried out by **MST. BADRUN NAHAR**, Registration No. **12-04946** 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 been duly acknowledged.

Dated: June, 2018

Dhaka, Bangladesh

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TO

MY BELOVED PARENTS

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GROWTH AND YIELD OF RED CABBAGE INFLUENCED BY ZINC UNDER DIFFERENT MULCH PRACTICES

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ABSTRACT

A field experiment was conducted in the Horticultural farm of Sher-e- Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to January 2018.The experiment consisted of two factors. Factor A: Zinc (4 levels): F_1 (0 ppm), F_2 (50 ppm), F_3 (100 ppm), F_4 (150 ppm) and Factor B: Mulches (3 levels): M_1 (No mulching/control), M_2 (White polythene mulch) and M_3 (Black polythene mulch). The experiment was laid out in Randomized Complete Block Design with three replications. Different Zinc and mulch materials showed significant variations with most of the parameters. In the case of zinc the highest gross yield (64.62 t/ha) and marketable yield (45.30 t/ha) were recorded from F_3 and the lowest gross yield (57.36) and marketable yield (39.72) from F_1. For mulching, the highest gross yield (68.16 t/ha) and marketable yield (47.97 t/ha) were recorded from M_3 and the lowest gross yield (54.66 t/ha) and marketable yield (37.89 t/ha) from M_1. For combined effect the highest gross yield (71.24 t/ha) and marketable yield (49.79t/ha) were recorded from F_3M_3 and the lowest gross yield (47.13 t/ha) and marketable yield (31.37 t/ha) from F_1M_1. From the result it was ensured that the treatment combination of 100 ppm zinc with black polythene mulch performed the highest yield than other treatment combination.

CONTENTS

CONT'D

CONT'D

CONT'D

CONT'D

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF APPENDICES

CONT’D

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro Ecological Zone
BADC	=	Bangladesh Agricultural Development Corporation
BARC	=	Bangladesh Agricultural Research Council
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
DAT	=	Days after Transplanting
df	=	Degrees of Freedom
FAO	=	Food and Agriculture Organization
FYM	=	Farm Yard Manure
LSD	=	Least Significant Difference
RH	=	Relative humidity
SE	=	Standard Error
SS	=	Sum of Square
t/ha	=	Tone per hectare
Wt.	=	Weight

CHAPTER I

INTRODUCTION

Red cabbage (*Brassica oleracea* L. var. *capitata*) is one of the most important cool season vegetables. Being under brassicaceae family its characters and requirements are similar to that of cabbage except it having pigments which imparts red colour to it. Red cabbage is a small, round headed type with dark red leaves (Bakar, 2006). Red cabbage synthesized and accumulated anthocyanins at all the developmental stages of vegetative growth. (Yuan, 2009). It is a biennial crop that is grown as an annual, unless it is grown for seed production. The transition from vegetative to reproductive growth is triggered by temperature. It is a dicotyledonous crop that has fibrous and finely branched roots (More, 2006). Red cabbage is a native crop in the Mediterranean region of Europe and now grows all over the world as a fresh market vegetable. (Yuan, 2009). In India, cabbage including red cabbage is cultivated in an area of 388 thousand ha producing 8755 thousand MT (Anonymous, 2015-16). It is used as salad, boiled vegetable, cooked in curries, used in pickling as well as dehydrated vegetable. Red cabbage is characterized by a higher content of health–enhancing components, compared to white cabbage (Tendaj *et al*., 2013). Red cabbage distinguished by exceptional health-enhancing properties and many beneficial sensory traits in recent years (Wojciechowska *et al.*, 2007).

In Bangladesh, still it is grown in a very limited scattered areas. Red cabbage cultivation is gaining popularity in Noakhali costal area, where farmers are happy with the harvest and price this season. The vitamin-enriched cabbage is growing in areas like Ewasbalia, Boyer Char, Char King, in South Hatiya along the Meghna River in Noakhali district. Red cabbage can be harvested in 60 to 70 days and 10 tons of red cabbage can be produced on one hectare of land, said some growers. In two upazilas Sadar and Hatiya farmers have made good profit from cultivation of red cabbage.

Zinc is one of the first micronutrients recognized as essential for plants and taken up by the plant in ionic form (Zn^{2+}). It is applied in the form of complex with a chelating agent like EDTA or ZnSO4 that is the principal salt, used as fertilizer. Zinc is known to occur in soil in a number of discrete chemical forms differing in their solubility and availability to plants (Sharawat and Burford, 1982). Zinc is a cofactor of over 300 enzymes and constituent of many proteins that are involved in cell division, nucleic acid metabolism and protein synthesis Crops yield are often limited by low level content of Zn in soils of arid and semi-arid regions (Cakmak, *et al.*, 1999). Zinc deficiency causes new leaves emerge white in color, older leaves may die, plant severely dwarfs (Singh and Gangwar, 1991). Cakmak (2000) stated that Zn deficiency may inhibit the activities of a number of antioxidant enzymes. Zinc is essential for the synthesis of tryptophan, a precursor of IAA which is essential for normal cell division and other metabolic processes and helps in the formation of chlorophyll (Wear and Hagler, 1968). Availability of zinc might have stimulated the metabolic and enzymatic activities thereby increasing the plant growth parameters (Kasturikrishana and Ahlawat, 2003).

Mulching is a practice of covering the surface of soil with plastics, organic and non-organic materials to reduce evaporation and soil temperature, especially in the root zone environment. Polyethylene mulches resulted in higher yield as compared to straw mulch and control (Salim *et al.*, 2008). Black plastic mulch lowers the soil temperature by preventing sunlight from reaching the soil surface and heating it and thus conserves soil moisture. It also controls weeds more successfully than other inorganic as well as organic mulches (Moniruzzaman *et al*., 2007). Use of mulches for early crop offers great scope in such a situation because of conserving moisture and improving soil temperature (Singh and Kamal, 2012). Red cabbage is a cool seasonal herbaceous leafy crop and it favors temperature range from 15-20°C (Yoshizawa, 1981). If the temperature exceeds 25°C this crop cannot form compact head. Mulching also provide acceptable temperature to the soil by protecting sunlight.

Red cabbage is a new member in vegetable cultivation of our country. Scientific finding about its cultivation relating to zinc and mulching for successful production is scanty in Bangladesh. But now a days there is a great demand of red cabbage in local market. Vegetable producers are interested to increase its production and use. Considering the present situation and above facts the present investigation was undertaken with the following objectives-

1. To find out optimum dose of zinc for red cabbage.

2. To know the effect of mulching on growth and yield of red cabbage cultivation.

3. To determine the interaction effect of zinc and mulch materials for cultivation of red cabbage in Bangladesh.

CHAPTER II

REVIEW OF LITERATURE

In Bangladesh Red cabbage is mainly grown as a leafy vegetable crop. The crop has received much attention by the researchers for increasing its growth and quality and other aspects of its production and utilization for different consumer uses in the very recent. A brief review related to research work was done on the "Growth and yield of Red cabbage (*Brassica oleracea* L.) Influenced by Different Level of Zinc under Efficient Water Management Practice" is presented in this chapter. An attempt has been made to cite as many references as possible. However, very limited research work has been done on these aspects in Red cabbage. Reference on various vegetables has been also incorporated.

2.1 Effect of Zinc:

Salim *et al*. (1995) reported that both Zn and cu ion had an inhibitory effect on the growth of spinach, cauliflower and parsley.

Bose and Tripathi (1996) observed that combined application of Zn, Mn and B at 30 and 60 days after transplanting resulted an increase in plant height, number of branches, number of fruits and yield per plant as compared to control in tomato.

In an experiment, Sharma *et al*. (1999) reported that soil application of 10 kg zinc sulphate and foliar application of 0.1% zinc sulphate was most effective for increasing growth, yield and seed quality of radish cv. Japanese white.

Dube *et al*. (2003) conducted a pot culture experiment on growth and yield of tomato (cv. Pusa Ruby) with different levels of Zn viz., 0, 1, 2.5, 5 and 10 mg kg-1 of soil as $ZnSO_4$ and they reported that the Zn @ 5 mg kg^{-1} of soil significantly superior in all growth parameters.

Kumar and Nair (1985) noted that the tuber yield of cassava increased by 12.8% with the application of Zn @ 2.5 kg ha^{-1} (10 kg $ZnSO_4$).

Kumar and Sen (2004) concluded that the application of Zn in okra improved plant height and number of branches significantly with increasing levels of zinc while, number of nodes on main axis of plant increased significantly up to 30 kg $ZnSO_4$ ha^{-1}.

Sivakumar *et al*. (2005) recorded highest plant height (101.80 cm), number of branches per plant (4.56) and early flowering with the application of 45 per cent RDF + PM @ 12.5 t ha^{-1} + $ZnSO_4$ @ 0.5 per cent as foliar spray in okra.

Sammauria and Yadav (2008) reported that increasing levels of Zn upto 7.5 kg Zn ha^{-1} as basal application increased number of branches per plant and pods per plant significantly whereas, seed per pod increased upto 5 kg Zn ha^{-1} in fenugreek.

At Hissar, Pandey *et al*. (1978) reported that soil application of $ZnSO_4$ @ 25 kg ha1 significantly increased the yield of cauliflower cv. Hissar-1.

Kumar and Nair (1985) noted that the tuber yield of cassava increased by 12.8% with the application of Zn @ 2.5 kg ha^{-1} (10 kg $ZnSO_4$).

Whereas, Balyan *et al*. (1988) found the maximum yield in cauliflower cv. Snowball-16 with the application of 160 kg N + 150 kg P_2O_5 + 20 kg $ZnSO_4$ per ha.

Singh *et al*. (1989) found that application of $ZnSO_4$ @ 20 kg ha^{-1} + 0.5% as foliar spray before flowering showed significant increase in seed yield of rainy season chillies.

Arora *et al*. (1990) concluded that the application of zinc induced earliest ripening and highest total yield in tomato.

Jana and Paria (1996) observed that the application of 0.5% Zn in garden pea at the onset of flowering and pod development stages increased the pod yield.

Balyan *et al*. (1994) applied N (0, 60, 120 and 180 kg) and Zn (0, 2.1, 4.2 and 6.3 kg) and found that marketable curd and yield of cauliflower increased with increasing levels of Zn to maximum (198.557 q/ha) at 4.2 kg ha^{-1} Zn and then decreased.

Ram *et al*. (2000) conducted a field experiment with 3 levels of N and 4 levels of Zn on radish cv. Kalyanpur Type-1 and obtained the maximum biological yield (393.53 q ha^{-1}) with 60 kg N + 20 kg $ZnSO_4$ ha^{-1}.

Raj *et al*. (2001) observed significant increase in yield, Zn and Fe content in fruit of brinjal cv. Bhagyamati with the soil application of $ZnSO_4$ 12.5 kg ha^{-1} along with 3 spray of 0.2% $ZnSO_4$ and 0.5% $FeSO_4$ at weekly interval. They recorded significantly maximum fruit yield (37.9 t ha^{-1}) with 23.66 per cent increase over control.

In tomato the effect of Fe and Zn observed in an experiment. The highest fruit yield of 39.88 t ha^{-1} was observed with soil application of 12.5 kg $ZnSO_4$ ha^{-1} followed by foliar spray of 0.2% $ZnSO_4$ and 0.5% $FeSO_4$ thrice at weekly intervals (Patnaik et al., 2001).

Raj *et al*. (2001) observed significant increase in yield and Zn and Fe content in fruits with their respective application either through soil or foliar. Among the treatment, soil application of 12.5 kg $ZnSO_4$ ha^{-1} along with spray of 0.2% $ZnSO_4$ and 0.5% $FeSO_4$ thrice at weekly interval recorded significantly maximum fruit yield 37.9 t ha^{-1} with 23.66 per cent increase over control in brinjal cv. Bhagyamati.

Dube *et al*. (2003) studied the effect of various Zn levels on growth and yield of tomato (cv. Pusa Ruby) in a pot culture experiment. Zinc was applied at 0, 1, 2.5 and 10 mg kg^{-1} of soils as $ZnSO_4$. Growth and fruit yield of tomato increased significantly with increasing levels of Zn. Application of Zn at 5 mg kg^{-1} of soil was found significantly superior in all growth parameters.

Raghav and Singh (2004) recorded maximum potato yield and growth with Zn @ 8 kg ha^{-1} as basal treatment and produced 16% higher yield as compared to control and 4.5% higher than the foliar application.

Kumar and Sen (2004) observed maximum fruits per plant (13.34), fruit yield per plant (218.55 g) and yield (147.20 q ha^{-1}) with the application of Zn 30 kg ha^{-1} as $ZnSO_4$ over control in okra.

Varghese and Duraisami (2005) recorded highest curd diameter (19.3 cm), curd weight (777g) and curd yield (28.79 t ha^{-1}) of cauliflower with the application of 1 kg B ha^{-1} + 2.5 kg Zn $ha^{-1.}$

Sammauria and Yadav (2008) obtained highest seed yield, straw yield and biological yield (982, 1906 and 2596 kg ha^{-1}), respectively through application of Zn @ 0.5 kg ha^{-1} in fenugreek.

Mishra *et al*. (1990) observed that application 3% suspension of zinc oxide for 12 hrs before transplanting gave the highest onion bulb yield (241.67 q ha^{-1}) and increase plant height, bulb size and bulb TSS content compared with control.

Balyan *et al*. (1994) recorded highest concentration of Zn uptake in leaves and curd of cauliflower (48.32 and 50.02 ppm), respectively cv. snowball-16 with the application of ZnSO4 @ 4 kg ha^{-1}.

Dube *et al*. (2003) reported that Zn @ 5 mg kg^{-1} of soil produced good quality fruit of tomato compared to its lower and higher doses (0, 1 and 2.5 and 10 mg kg^{-1} of soil), respectively.

Divrikli *et al*. (2003) observed Zn content in cabbage, spinach and lettuce from 0.3 to 3.4 mg kg^{-1}.

Srivastava *et al*. (2005) recorded maximum TSS content of 36.07 and 36.330 brix with 1.2% $ZnSO_4$ and 1.0 per cent boric acid, respectively as foliar spray in garlic.

2.2 EFFECT OF MULCHING:

Efficiency of different mulches is again a point to be considered in an experiment while Hossain (1999) working with different mulches on cabbage in the Department of Horticulture, Bangladesh Agricultural University, Mymensingh and observed maximum gross and marketable yields (116.67 t/ha and 97.53 t/ha, respectively) from black polythene mulch and the lowest (92.33 t/ha and 40.56 t/ha) was from the control condition.

Saifullah *et al*. (1996) while working with mulches and irrigation on cabbage, in the Horticulture Farm, Bangladesh Agricultural University, Mymensingh and found that yield and most of the yield contributing characters like plant height, number of loose leaves per plant, diameter and thickness of head, weight of loose leaves, stem, roots, head, whole plant and total dry matter per head were significantly increased by the application of irrigation and mulches. Mulching was found to be more effective during the early stage of plant growth. The highest marketable yield was obtained by irrigation treatment (37.09 t/ha) followed by black polythene (33.16 t/ha), water hyacinth (26.91 t/ha), sawdust (20.66 t/ha) and straw (24.64 t/ha) and the lowest (12.68 t/ha) by the control condition. They concluded on based upon their findings that as an alternative to irrigation, water hyacinth and straw can be adopted as feasible mulches to increase the yield of cabbage and also by conserving the residual soil moisture.

Bragagnolo and Miclniezuk (1990) found that mulches increased the growth and yield of cabbage and as well as marketable yield. Similar results also reported by Ashworth Harrison conducted an experiment with mulches on cabbage in the Department of Botany, University of Edinburgh, UK and found that mulching increased the marketable yield of cabbage.

M. Y. Sarkar *et al*. (2003) investigate the Effect of Different Sources of Nutrients and Mulching on Growth and Yield Contributing Characters of Cabbage and they found that the use of black polythene sheet mulch produced the highest marketable yield (70.24 t ha^{-1}) and the lowest (45.13 t ha^{-1}) in this respect was observed without mulch. The treatment combination of organic + inorganic fertilizers with black polythene sheet mulch gave the highest marketable yield (97.83 t ha^{-1}) of cabbage.

Easmin, D. *et al.* (2013) investigate the Effect of Different Levels of Nitrogen and Mulching on the Growth of Chinese Cabbage and they found that The highest Chinese cabbage plant, spread of plant (44.50cm, 58.28cm) during harvest period was recorded in black polythene mulch and the shortest plant and spread of plant (37.60cm and 49.58cm) was recorded in no mulch i.e. control. The highest days to start of head formation of Chinese cabbage (45.37) was recorded in no mulch and the lowest days (41.17) were recorded in black polythene mulch. The highest marketable yield per hectare of Chinese cabbage (123.27 ton) was recorded in black polythene mulch and the lowest yield (76.51 ton) was recorded in no mulch. In each and every case maximum growth and yield contributing characters and yield was observed in black polythene mulch and the reverse result was recorded in no mulch.

M.Moniruzzaman *et al.*(2007) was conducted the experiment on Effects of Irrigation and Different Mulches on Yield of Profitability of Cauliflower and they found that Irrigation at 7 days interval and mulching with black polythene independently as well as in combination produced maximum values for yield attributes and marketable yield of cauliflower. The highest curd yields of 30.38 and 29.40 t ha^{-1} were obtained from 7 days irrigation interval with black polythene mulch in 2000-01 and 2001-02, respectively. The lowest curd yields of 10.50 and 10.04 t ha^{-1} were obtained from without irrigation and mulching in 2000-01 and 2001-02, respectively.

Gordon *et al.* (2010) was conducted the experiment on "Effect of Mulch Types and Mineral Fertilizer Rates on Cabbage (*Brassica Oleracea* var. Capitata) Growth and Yield in the Highlands of Rwanda" and they found that application of black plastic and wheat straw mulch significantly increased cabbage stem diameter, height, leaf area index (LAI), head diameter and weight compared to bare soil.

Islam *et al*. (2002) investigated the effect of planting time, mulching and irrigation on the growth and yield of cabbage cv. Atlas-70. Mulching and irrigation significantly affected the growth and yield of cabbage. The highest gross yield (71.85 kg/plot) was obtained from the black polyethylene mulch followed by water hyacinth mulch (65.99 kg/plot). Considering marketable yield, both black polyethylene mulch (103.01 t/ha) and water hyacinth mulch (90.99 t/ha) exerted statistically similar effects followed by irrigation at 15 days interval (85.85 t/ha), whereas non-mulching and non-irrigated plots (control) exhibited the lowest marketable yield (38.87 t/ha).

Sarker *et al*. (2003) stated that mulching had no marked effect on harvest index, but had significant effect on rest of the parameters studied. The use of black polythene sheet mulch produced the highest marketable yield (70.24 t/ha) and the lowest (45.13 t/ha) in this respect was observed without mulch.

Awasthi *et al*. (2005) reported that soil mulched with organic mulches showed beneficial effect in lowering the soil temperature at 20 cm depth during summer months (1.1-5.6°C), while increase in soil temperature was recorded during the peak winter months i.e. December- January (0.6-3.2°C). Significant increase in soil temperature was recorded in black and white polyethylene during the winter months December-January (2.7-5.1°C) over control. Organic mulches reduce maximum temperature of soil during summer months.

Jamil *et al*. (2005) observed the effects of different type of mulches (plastic, straw & sawdust, excluding, control) and their duration (one month & whole season) on the growth and yield of garlic. They found that straw and plastic mulches increased the bulb yield and yield components, irrespective of their duration. Straw mulch is recommended for the garlic production based on better overall performance than the others and also for being cheaper and organic in nature.

Awodoyin *et al*. (2007) conducted experiments to assess the impacts of different mulching materials on weed control, soil temperature, soil moisture depletion and performance of tomato (*Lycopersicon esculentum* Mill.). The crop growth and fruit yield were studied under plastic (grey-on-black), woodchip (Teak) and grass *(Pennisetum*) mulches, with hand weeded and un-weeded as controls. They also assessed the weed dry matter and species spectrum, soil temperatures at 5-cm and 15-cm depths, and soil moisture depletion. Compared to unwedded control that had the least total fruit yield (2.7 t/ha in 1998 and 4.2 t/ha in 2004), mulch types and hand weeded treatments increased the fruit yield by 152-237% in 1998 and 188202% in 2004. Compared to mean pooled fruit yield from all mulched plots, unwedded treatment reduced tomato fruit yield by about 65% and 66% in 1998 and 2004, respectively. The weed control efficiencies of the mulches ranged between 91% and 100%. Dicotyledon weed species dominated the plots in the two years accounting for 81.8% in 1998 and 90% in 2004. The number of low-growing weed species enumerated on the plots was 11 in 1998 and 18 in 2004. After four weeks of no rainfall in 1998, moisture loss was least (1.68±0.10%) under plastic mulch and highest (13.96±0.08%) on the unweeded plot. The differences between morning and afternoon soil temperatures at 5 cm depth were low under grass mulch, woodchip mulch and unweeded control (5.0-5.9°C) but high under plastic mulch and hand weeded control (8.7-8.9°C). Mulches are effective in weed control and conservation of soil moisture, and the plant-based mulches are most effective in reducing soil temperature. These improvements of crop growing environment resulted in increased tomato growth and fruit yield.

Moniruzzaman *et al*. (2007) found that irrigation at 7 days interval and mulching with black polythene independently as well as in combination produced maximum values for yield attributes and marketable yield of cauliflower. The highest curds yields of 30.38 and 29.40 t/ha were obtained from 7 days irrigation interval with black polyethylene mulch. The lowest curds yields of 10.50 and 10.04 t/ha were obtained from without irrigation and mulching. Seven days interval irrigation and mulching with forest leaves (mango leaves) in combination gave the highest benefit: cost ratio (6.51) closely followed by 14 days interval irrigation with the same mulch (6.48). But maximum marginal rate of return (1156.89%) was recorded from the combination of 14 days interval irrigation and mulching by mango leaves followed by irrigation at 21 days interval with the same type of mulch (936.92%).

Salim *et al*. (2008) found a positive impact of mulch on yield and yield attributes of the cauliflower crops. The highest marketable yield (31.32t/ha) was obtained from hybrid variety Snow crown with mulch was 35.16% higher than without mulch. Other two varieties also produced higher yield under mulched condition than the without mulch. The production cost was higher in mulched treatment by Tk. 1510. A net additional return of Tk. 97800, 41040 and 30840 from the varieties Snow crown, Poushali and IPSA-1 respectively, was obtained due to mulching.

Anisuzzaman *et al*. (2009) evaluated effects of planting time and mulches on bulb growth and seed production of onion they observed that mulches had significant influence on almost all parameters studied. Growth and seed production was accelerated by black polythene. Seed yield was 529.06 kg/ha where black polythene mulch was used.

Kashyap *et al*. (2009) stated that in broccoli important yield attributing characters viz., head diameter (20.25 cm), head weight (603.50 g) were highest under drip irrigation at 120% evaporation replenishment with black polythene mulch.

Ekwu *et al*. (2010) studied the effect of mulching (grass mulch) on the vegetative growth and green pod yield of okra. The results showed that mulched plots, which received 140 kg N/ha produced the highest number of fruits. The weight and length of fruits was higher on the mulched plots. Non-mulched plots consistently produced least values in all the parameters that were measured.

El-Kader *et al*. (2010) stated that mulching process can help to improve some soil properties and yield of vegetables crops. The results of their study showed that there were more increases in soil temperature under blue polyethylene than under other treatments. The recorded soil surface temperature was lowest under rice straw. The soil moisture content increased under colorless polyethylene more than others treatments. The highest value of cowpea seed yield was 2.83 Mg/ha under both colorless polyethylene and rice straw treatments. Using mulching with rice straw or colorless polyethylene suggested for enhancing soil structure, water management, growth and cowpea yield components as indicated in this work.

Mehta *et al*. (2010) reported that the maximum plant height, harvest duration and fruit weight was obtained in treatment combination L_1M_1 (single leader + black plastic mulch), whereas highest yield/plant was recorded in L_2M_1, i.e. double leader + black plastic mulch. The incidence of fruit rot was minimum in L_1M_1 (single leader + black plastic mulch), closely followed by L2M1 (double leader + black plastic mulch) and L_3M_1 (triple leader + black plastic mulch).

Vazquez *et al*. (2010) found that the use of plastic mulch compared to bare soil did not improve the yield of cauliflowers. Excess of N fertilizer in mulched plots increased the aboveground crop residues. The amount of nitrogen in crop residues increased in line with application rates of nitrogen in plots with plastic mulch; that nitrogen may be used either by the following crops or lost by leaching.

Bhatt *et al*. (2011) studied the effect of different mulch materials viz., black plastic, clear plastic, dry leaves, pine needles, green twigs of non-fodder plants, forest litter and FYM on vegetative characters, yield and production economics of summer squash. They found that maximum plant height (38.11 cm), plant spread (142.39 cm), number of leaves per plant (41.85), root length (36.83 cm) and yield (62.72 t/ha) were recorded in black plastic mulch when compared with other treatments. The black plastic mulch not only advanced the harvesting time but also produced 74.17 per cent higher fruits yield than the control. Amongst the organic mulches, pine needles and forest litter were found equally effective in improving vegetative characters, which ultimately resulted in higher yields. Mulching with black plastic in summer squash was also found most economical with a net return of 232628.70 per hectare and Benefit: Cost ratio of 2.61.

Carvalho *et al*. (2011) evaluated the reported that cabbage productivity has been affected by the irrigation interval and by mulching. The maximum water use efficiency was obtained with irrigation frequency of 12 h and mulching adoption, corresponding to 110.49 Mg/ha/mm, associated to a lower soil moisture variation along the experiment. Mulching relevance was highlighted for the irrigation interval equal to 48 h, contributing to control moisture losses, and to keep cabbage yield.

Ewulo *et al*. (2011) observed that tillage increased dry matter yield of sorghum significantly, while dry matter yield, plant height, leaf area and grain yield were significantly increased by mulching. Tillage plus mulching significantly enhanced performance of pepper and sorghum.

Lopes *et al*. (2011) evaluated the growth of tomato plants under the mulching with uncovered soil, black polyethylene film, silver polyethylene film, white polyethylene film and black polypropylene TNT. They reported that mulching influenced the development of dry matter accumulation in leaves, branches and fruits and the TNT promoted the highest averages. The fruits behaved as the preferential drain of the plant. The TNT was the mulching that has promoted the highest average for the leaf area index and absolute and relative growth rates. The leaf area ratio, specific leaf area and net assimilation rate were not influenced by cover crops.

Zedan *et al*. (2011) studied the effect of three dates (28 September, 12 October, 26 October 2010) and four colors from plastic mulching (control, colorless, yellow and black). For mulching, the black plastic had the significant increment for all vegetative growth and yield characters except the percentage of dry material of vegetative growth and cloves, the significant increment was for control, which the first date the significant increment, by using by black plastic, in all vegetative growth and yield characters except the percentage of dry material of vegetative growth and cloves, the significant increment was for the third date for control.

Lopez-Marin *et al*. (2012) stated that black and transparent polyethylene (PE) mulch were compared with bare soil (control) and three biodegradable plastic mulch materials (MB green, MB black, MB transparent). Data loggers were installed 7 cm deep into the soil under various mulches to record soil temperature. Mulch degradation, soil temperature and broccoli growth and biomass were assessed. Plant growth, estimated as the total dry weight produced, was similar for MB and PE treatments. Results indicated that soil temperatures under the biodegradable mulches were similar to the PE mulch. All mulch treatments were successful for weed control. Mechanical analyses indicated that the MB had initially a lower resistance and elongation percentage at break point than PE.

Singh and Kamal (2012) studied the effect of soil mulching with black plastic sheets on soil temperature and tomato yield from May to September in the temperate region of Uttarakhand. Highest soil temperature was obtained under the black plastic mulch during the early growth season due to less shade on the surface. The difference in temperature between mulched and bare soil was 2.2 to 3.4°C. Black plastic mulch significantly affects the tomato yield. The yield increased with black plastic mulch from 20.7 to 29.8% as compared to bare soil.

Masarirambi *et al*. (2013) determined the effect of white plastic and sawdust mulches on growth yield of „Savoy" baby cabbage (*Brassica oleracea.* var *bullata*). A control where no mulch was applied was also included in the experiment. The results indicated that mulch type significantly ($p<0.05$) affected growth and yield of „Savoy" baby cabbage, weed infestation and moisture conservation on a loamy soil. There was no significant difference in yield of cabbage heads from plots mulched with white plastic or sawdust while the control produced relatively the lowest yield of „Savoy" baby cabbage. Both white plastic and sawdust mulches conserved moisture. When growing „Savoy" baby cabbage during the warm season, it is recommended to mulch with white plastic or sawdust in order to realize near perfect growth and yield, as well to conserve soil moisture and weed suppression by white plastic.

Spehia *et al*. (2013) reported that plant height, equatorial and polar diameter of the onion bulbs was observed to be significantly affected by irrigation methods, levels and mulching treatments. Application of polyethylene mulching increased the water use efficiency to the tune ranging from 5-15%.

Kosterna (2014) evaluated the effect of plants covering and the kind of organic mulch applied to soil mulching on the yield and selected component of nutritive value in Milady F_1 broccoli cultivated for early harvest. The application of polypropylene fiber contributed to a significant increase in the marketable yield of broccoli on average by 5.25 t/ha, weight of head by 0.10 kg and length of arc by 1.44 cm. Increase of the content of chemical components as a result of plants covering amounted to 1.76% for dry matter, 2.50 mg/100 g fresh matter (FM) for ascorbic acid, 0.65% FM for total sugar and 0.15% FM for monosaccharide's. All kinds of straw contributed to an increase in the broccoli yield and improvement its parameters. The highest marketable yield and weight of head was obtained in the plots mulched with buckwheat straw. Irrespective of covering, cultivation on the mulch with buckwheat straw contributed to a slight decrease in dry matter, total sugars content, whereas cultivation on the rye straw decreased ascorbic acid content.

CHAPTER III

MATERIALS AND METHODS

An experiment was conducted in the Horticultural farm of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to January 2018 to study the growth and yield of red cabbage influenced by zinc under different mulch practices. This chapter includes materials and methods that were used conducting in the experiment. It consists of a short description of locations of the experimental site, characteristics of soil, climate, materials used for the seedlings, treatment of the investigation, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data collection procedure, economic and statistical analysis etc. The details regarding materials and methods of this experiment are presented below under the following headings **–**

3.1 Experimental Site:

Experimental site of the present trial is situated in 23°74/N latitude and 90°35/E longitude with an elevation of 8.2 meter from sea level (Anon., 1989).

3.2 Characteristics of Soil

The soil of the experimental area was non-calcarious dark grey and belongs to the Modhupur Tract (UNDP, 1988) under AEZ 28. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The pH level of the soil was 5.6. The characteristics of the soil under the experimental plot were analyzed in the SRDI, Soil testing Laboratory, Khamarbari, Dhaka.

3.3 Weather Condition of the Experimental Site:

The geographical circumstances of the experimental site was under the subtropical climate, characterized by three distinct seasons, the monsoon or rainy season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al*.

1979). The total annual rainfall of the experimental site was 28.55 mm and averages monthly the maximum and the minimum temperature were 24.40°C and 20.93°C, respectively.

3.4 Planting Materials

In this research work, Seeds of Ruby King of Red cabbage were used which was produced by Takii and Co. Ltd. Japan. The seeds were collected from Dhaka seed store, Siddique Bazar, Dhaka.

3.5 Raising of seedling:

The seedlings were raised at the Horticultural Farm, SAU, Dhaka under special care in a 1 m x 1 m size seed beds. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease cupravit fungicide was applied. Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Ten (10) grams of seeds were sown in each seedbed on October 10, 2017. After sowing, the seeds were covered with finished light soil. At the end of germination shading was done by bamboo mat (chatai) over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding and mulching were done.

3.6 Design of the experiment: The experiment will be consisted two factors with three replication and deign was followed by Randomized Complete Block Design

Factor A: Four levels of Zinc viz.	Factor B: Mulches (3 levels)
F_1: Control	M_1: no mulches
F_2:Zn_{50ppm}	M_2:White polythene
F_3:Zn_{100ppm}	M_3:Black polythene
F_4:Zn_{150ppm}	

There are 12 treatment combination such as F_1M_1, F_1M_2, F_1M_3, F_2M_1, F_2M_2, F_2M_3, F_3M_1, F_3M_2, F_3M_3, F_4M_1, F_4M_2 and F_4M_3.

3.7 Layout of the Experiment

The experimental plot was laid out in Randomized Complete Block Design with three replications. The layout of the experiment was prepared for distributing the treatment combinations in each plot of each block. Each block was divided into 12 plots where 12 treatment combinations were allotted at random. There were 36 unit plots altogether in the experiment. The size of each unit plot 1.8 m × 1.35 m. The distance between blocks and plots were 0.5 m and 0.25 m respectively.

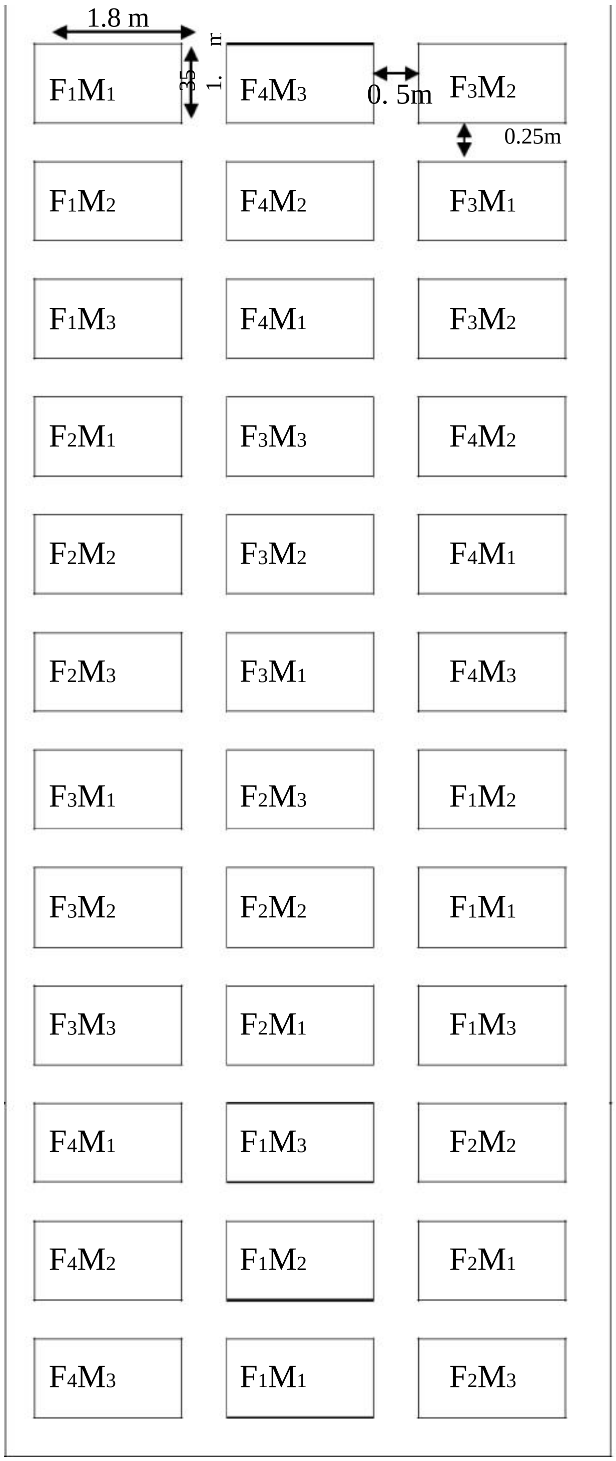
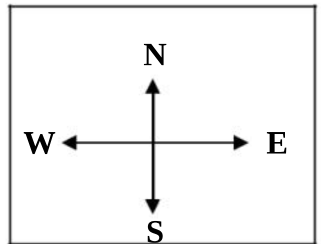


Fig. 1. Layout of the experimental plot

LEGEND



Treatments

Factor A: Zinc (4 levels)

1. F_1 = 0 ppm (Control)
2. F_2 = 50 ppm
3. F_3 = 100 ppm
4. F_4 = 150 ppm

Factor B: Mulches (3 levels)

1. M_1 = No mulch (Control)
2. M_2 = White polythene
3. M_3 = Black polythene

3.8 Preparation of the main field

The selected experimental plot was opened in the last week of October 2017 with a power tiller and was exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil for planting of Red cabbage seedlings. The experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in 3.6. Recommended doses of well- rotten cow dung manure and chemical fertilizers as indicated in 3.9 were mixed with the soil of each unit plot.

3.9 Application of manure and fertilizers

Well decomposed cowdung 10 t/ha was applied in the time of final land preparation. The sources of fertilizers used for N, P, K, were taken from the urea (160 kg/ha), TSP and MP (200 kg/ha), respectively. The entire quantity of TSP and ½ of MP were applied during the final land preparation. Urea was applied in equal three installments at 10, 20, 30 DAT and rest of MP was also applied after transplanting. Foliar application of zinc sulphate were applied at 20, 30, 45 days after transplanting.

3.10 Transplanting of seedlings in the main field:

Healthy and uniform sized thirty days old seedlings were transplanted in the main field on November 10, 2017. The seedlings were uprooted carefully from the seedbed to avoid any damage to the root system. To minimize the roots damage of the seedlings the seedbed was watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. During transplanting a spacing of 50 cm x 40 cm (between row to row and plant to plant), were maintained. The seedlings were watered immediately after transplanting. Transplanted A number of seedlings were also planted in the border of the experiment plots for gap filling if necessary later on.

3.11 Application of treatment:

This experiment was comprises of Mulches of black polythene sheet and white polythene sheet were provided immediately before seedling transplanting where small holes were made on the mulches with maintaining proper spacing for seedling transplanting with three zinc levels (50 ppm, 100 ppm and 150ppm). The treatments are as follows:

1. F_1= Mulched and non-mulched (control) plots sprayed without zinc (control),

2. F_2= Mulched and non-mulched (control) plots sprayed with 50 ppm zinc

3. F_3= Mulched and non-mulched (control) plots sprayed with 100 ppm zinc

4. F_4= Mulched and non-mulched (control) plots sprayed with 150 ppm zinc

3.11.1 Preparation of zinc sulphate solutions ($ZnSO_4$) solutions (50 ppm, 100 ppm and 150 ppm):

50 mg of zinc sulphate ($ZnSO_4$) was dissolved in 1 L of water to prepare 50 ppm zinc solution. Similarly, 100 mg, 150 mg of zinc sulphate ($ZnSO_4$) was dissolved in 1 L of water to prepare 100 ppm and 150 ppm zinc solution respectively.

3.12 Intercultural operation:

When the seedlings were started to emerge in the seed beds and they were always kept under careful observation. After emergence of seedlings, various intercultural operations were accomplished for better growth and development of the Red cabbage seedlings.

3.12.1 Irrigation

Light over-head irrigation was provided with a watering cane to the plots immediately after transplanting. The un-mulched plot had to be irrigated more frequently than the mulched plots. As a consequence, the amount of irrigation water was much higher in un-mulched plots than those of other mulched plots.

3.12.2 Gap filling

Dead, injured and week seedlings were replaced by healthy one from the stock which were kept on the border line of the experimental plot. Those seedlings were re-transplanted with a big mass of soil with roots to minimize transplanting shock. Replacement was done with healthy seedling having balls of earth with were also planted on the same date on border line. The transplanted seedlings were shaded and watered for 07 days continued for the proper establishment of the seedlings.

3.12.3 Weeding:

No weed was found in the plots which was covered by polythene mulch, less weed was noticed in plots which were covered by white polythene. But huge numbers of weed were found in the control condition. Weeding was done three times in these plots considering the optimum time for removal weed.

3.12.4 Plant protection

The crop was protected from the attack of insect-pest by spraying Malathion. The insecticide application was allowed fortnightly as a matter of routine work from transplanting up to the end of head formation.

3.12.5 Harvesting

The crop was harvested depending upon the maturity of Red cabbage. Harvesting was done manually. Enough care was taken during harvesting period to prevent damage of leaf.

3.13 Data recording

The data were collected from the inner rows of plants of each treatment to avoid the border effect. In each unit plot, 5 plants were selected at random for data collection. Data were collected in respect of the plant growth characters and yield of Red cabbage. Data on plant height, plant spread and number of loose leaves were counted at 30, 45, 60, days and at harvest. However, for gross and marketable yields per plot all the 9 plants of each unit plot were considered. All other parameters were recorded at harvest. The following parameters were set up for recording data and for the interpretation of the results. Data were recorded on the following parameters:

3.13.1 Plant height

The height of plant was recorded in centimeter (cm) at 30, 45, 60 days after transplanting (DAT) by using a meter scale. The height was measured from the ground level to the tip of the growing point of an individual plant. Mean value of the 5 selected plants was calculated for each unit plot.

3.13.2 Plant spread

The spread of plant was measured with a meter scale as the horizontal distance covered by the plant. The data were recorded from randomly 5 selected plants at 30, 45, 60 days after transplanting and mean value was counted and was expressed in centimeter (cm).

3.13.3 Number of leaves per plant

Number of unfolded leaves per plant was counted at 30, 45, 60 days after transplanting from 5 plants and mean value was recorded.

3.13.4 Leaf length

Length of leaves of five-tagged plants was measured at 30, 45, 60 days after transplanting and mean was calculated for each treatment.

3.13.5 Leaf Breadth (cm)

Breadth of leaves of five-tagged plants was measured at 30, 45, 60, days after transplanting and mean was calculated for each treatment.

3.13.6 Fresh weight of total plant

The fresh weight of plant at harvest was recorded as the average of 5 plants selected at random from each unit plot. The weight of the total plant was recorded immediately after harvest.

3.13.7 Number of unfolded leaves per plant

Number of unfolded leaves per plant was counted at harvest from 5 plants and mean value was recorded.

3.13.8 Fresh weight of unfolded leaves per plant

The fresh weight of unfolded leaves was taken which was collected at the harvest time and expressed in grain and mean value for a unit plant was recorded.

3.13.9 Length of stem

The length of stem at harvest was recorded in cm with a meter scale as the distance from the ground level to the base of the unfolded leaves and mean value was recorded.

3.13.10 Diameter of stem

Diameter of stem was taken which was collected at the harvest time and expressed in cm and mean value for a unit plant was recorded.

3.13.11 Length of roots

After harvest root length was recorded from the root-shoot junction to the tip of the main root and was expressed in centimeter with the help of a meter scale and then recorded in per plants.

3.13.12 Thickness of head

The thickness of head was measured in centimeter (cm) with a meter scale as the vertical distance from the lower to the upper most leaves of the head after sectioning the head vertically at the middle position and mean value was calculated.

3.13.13 Diameter of head

The heads from sample plants were sectioned vertically at the middle position with a sharp knife. The diameter of the head was measured in centimeter (cm) with a meter scale as the horizontal distance from one side to another side of the widest part of the sectioned head and mean value was recorded.

3.13.14 Fresh weight of head per plant

The heads from sample plants were cleaned with removing unfolded leaves. The weight of every head were measured a weighing scale and mean values was counted.

3.13.15 Dry matter content of head

A sample of one hundred grams chopped head from 10 selected plants was dried freshly in the direct sun light for two days and then it was dried in an oven at 65°C for 72 hours, until constant weight was achieved. The dry weight of the sample was recorded in gram and the mean value was calculated.

Then the percent dry matter content in heads was calculated by using following formula

$$\% \text{ Dry matter of head} = \frac{\text{Dry weight of head}}{\text{Fresh weight of head}} \times 100$$

3.13.16 Gross yield per plot

Gross yield of Red cabbage per plot was recorded as the whole plant weight of all the plants within a plot and was expressed in gram. Gross yield included weight of head, unfolded leaves and stem.

3.13.17 Gross yield per hectare

Gross yield per hectare was calculated by converting the weight of plot yield to hectare and was expressed in ton.

3.13.18 Marketable yield per plot

Marketable yield per plot was recorded as the whole plant weight of all the plants within a plot and was expressed in gram. Marketable yield included only the weight of head.

3.13.19 Marketable yield per hectare

The weight of all compact head excluding leaves, stem and root produced in a plot was taken and converted into yield per hectare and was expressed in ton.

3.13.20 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the level of significance of the different level of Zinc and mulches on yield and yield contributing characters of Red cabbage. The analysis was performed by F-test and the significance of the difference between pairs of treatment means was evaluated by the Least Significance Difference (LSD) test at 5% level of significance. (Gomez and Gomez, 1984)

Effect of black polythene at vegetative stage of red cabbage

Effect of white polythene at vegetative stage of red cabbage

Effect of control at vegetative stage of red cabbage

picture of red cabbage at reproductive stage

Spraying of zinc solution at vegetative stage of red cabbage

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the Growth and Yield of Red Cabbage Influenced by Zinc under Different Mulch Practices. The analysis of variance (ANOVA) of the data on different yield components and yield of Red cabbage are given in Appendix (III-XXXII). The results have been presented and discussed, and possible interpretations have been given under the following headings-

4.1 Plant height (cm)

Plant height varied statistically due to the different level of zinc at 30, 45, and 60 DAT (Appendix III-V). Zinc100 ppm treatment gave the tallest (22.70 cm) plant at 30 DAT which was statistically similar (22.25 cm) to at 150 ppm, while 0 ppm gives the shortest (20.31cm) plant height. The tallest (36.25 cm) plant was observed from treatment F_3 which was closely followed (35.63 cm) with F_4 treatment and the shortest (33.98cm) plant was from the F_1 treatment at 45 DAT (Figure 2). At 60DAT the tallest (39.38 cm) plant was recorded from the treatment F_3 which was statistically identical (38.84 cm) with F_4 treatment and the shortest (38.08cm) plant was from the F_1 treatment. The results indicated that zinc helps to increases plant height and the tallest plant was recorded in 100ppm zinc than control condition. Increase in plant height as a result of Zn application may be due to the essential metabolic roles Zn plays in the plant, the most significant being its activity as a component of many enzymes (Lindsay, 1972).

Different mulching showed significant differences on the plant height at 30, 45, 60 DAT. The tallest (24.16cm) plant was recorded from (black polythene mulch) M_3 which was closely followed (21.56cm) by M_2 (white polythene) and the shortest (19.50 cm) was from Control i.e. no mulch at 30 DAT (Figure3).

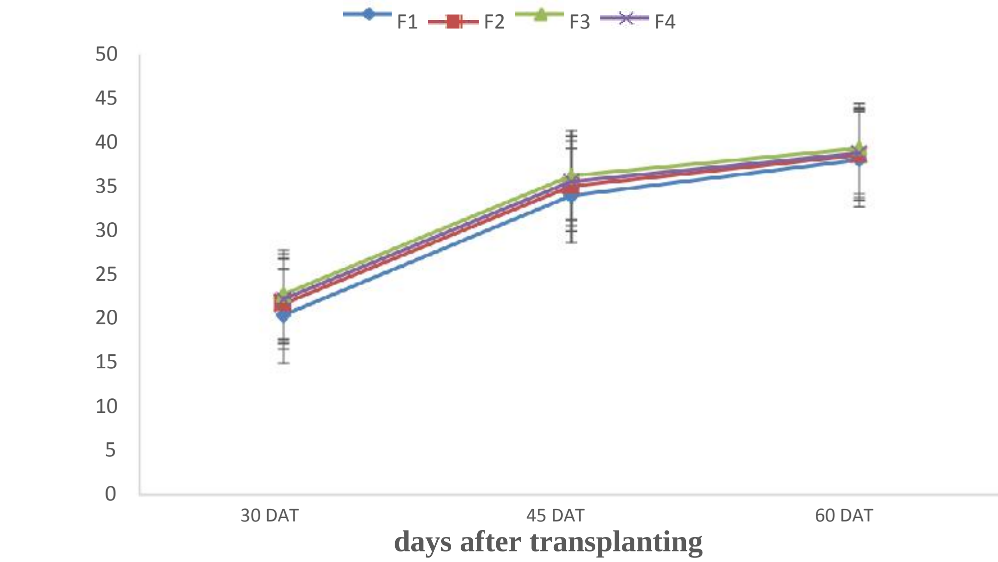


Fig 2 :Effect of zinc on plant height at different days after transplanting of red cabbage (LSD at 5% level)

F_1= No zinc (Control), F_2=50 ppm zinc, F_3=100 ppm zinc F_4=150 ppm zinc

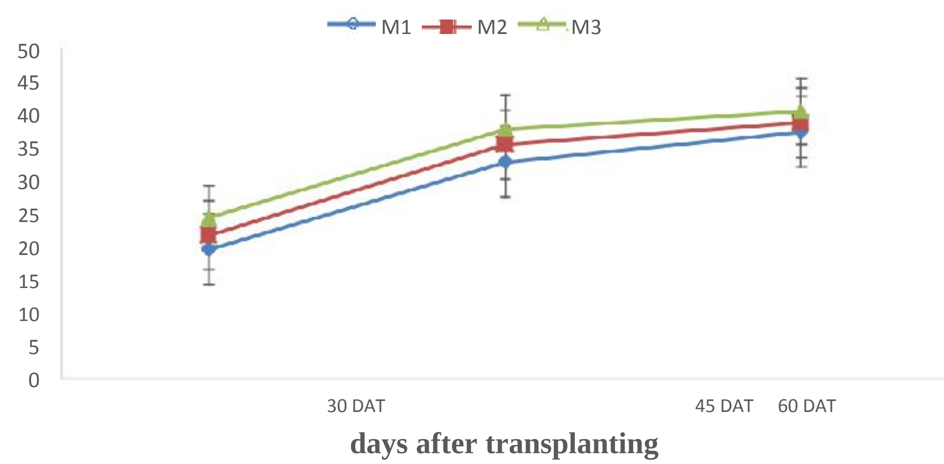


Fig 3: Effect of mulch materials on plant height at different days after transplanting of red cabbage (LSD at 5% level)

M_1=No mulch (Control), M_2=White polythene mulch, M_3=Black Polythene

At 45 DAT the tallest plant (37.69cm) was found from M_3 followed (35.30cm) by M_2 treatment, while the shortest (32.69cm) plant was obtained from the control treatment. The tallest plant was recorded (40.00) cm from the treatment of M_3 closely followed (38.61cm) by M_2 and the shortest (37.25cm) plant was from the control at 60 DAT. From the results it was found that mulching increase the plant height and black polythene mulch was better than the white polythene mulch under the present trial. Acharya (1988) and Matsumura (1981) reported earlier that mulching increase cabbage plant height.

The plant height significantly differed by the interaction effect of zinc and mulch. The tallest (25.26cm) plant was recorded at 30 DAT from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment combination F_1M_1 (zinc 0 ppm + no mulch) gave the shortest (17.20cm) plant (Table 1). At 45 DAT significant variations in terms of plant height was also observed among the treatments and the tallest (38.46cm) plant was observed from the treatment combination of F_3M_3 whereas the shortest (30.33cm) was recorded from F_1M_1. At 60 DAT the tallest (41.46cm) plant was recorded from the treatment combination of F_3M_3 and the shortest (36.73cm) was recorded from F_1M_1. From the results it was revealed that 100 ppm zinc with black polythene mulch favored the plant height in comparison with the other treatments that used in the present experiment. Zinc and mulching increased the growth and development as well as ensure the availability of other nutrients for plant and the ultimate results is the tallest plant than control condition. Similar results also reported by Agele *et al*. (2004) and Rahman *et al*. (1989) from their experiment.

4.2 Spread of plant (cm)

A statistically significant variation was recorded in terms of spread of plant due to the different level of zinc at 30, 45, 60 DAT (Appendix XV-XVII). Zinc 100 ppm treatment (F_3) gave the maximum (33.26cm) spread of plant at 30 DAT which was closely followed (32.75cm) with F_4 treatment at 150 ppm while

Table 1. Interaction effect of different level of zinc and mulch materials on plant height and spread of Red cabbage

Treatment combination	Plant height(cm)			Spread(cm)		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
F_1M_1	17.20 h	30.33 g	36.73 h	22.93 h	44.53 f	48.33 h
F_1M_2	20.67 fg	34.80 de	38.13 e-g	30.93 d-f	52.13 b-d	53.47 d-f
F_1M_3	23.07 cd	36.83 a-c	39.40 cd	34.13 a-c	53.87 bc	55.53 bc
F_2M_1	20.07 g	32.53 f	37.13 h	28.67 g	48.20 e	51.47 g
F_2M_2	21.33 e-g	35.13 de	38.57 d-f	32.27 c-e	52.60 b-d	54.13 c-e
F_2M_3	23.73 bc	37.47 ab	39.93 bc	34.60 a-c	55.40 ab	56.13 a-c
F_3M_1	20.43 g	34.37 de	37.67 f-h	30.27 e-g	51.33 c-e	52.80 e-g
F_3M_2	22.40 c-e	35.93 b-d	39.00 de	33.13 b-d	53.53 b-d	55.33 b-d
F_3M_3	25.27 a	38.47 a	41.47 a	36.40 a	58.53 a	57.60 a
F_4M_1	20.30 g	33.53 ef	37.47 gh	29.93 fg	49.67 de	52.07 fg
F_4M_2	21.87 d-f	35.37 cd	38.73 de	32.93 a	53.20 b-d	54.47 c-e
F_4M_3	24.60 ab	38.00 a	40.33 b	35.40 ab	55.87 ab	56.67ab
S.E	0.44	0.53	0.30	0.85	1.22	0.62
Significance level	0.00	0.00	0.00	0.00	0.00	0.00

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.

S.E=Standard Error

F_1= No zinc (control)

F_2=50 ppm zinc

F_3=100 ppm zinc

F_4=150 ppm zinc

M_1=No mulch (control)

M_2=White polythene mulch

M_3=Black Polythene mulch

0 ppm zinc as treatment F_1 gave the minimum (29.33cm). The maximum (54.46 cm) spread of plant was observed from treatment F_3 which was statistically with F_4 treatment and the minimum (50.17cm) was found from the F_1 treatment at 45 DAT (Figure 4). At 60 DAT the maximum (55.24cm) spread of plant was recorded from the treatment F_3 which was statistically identical (54.40 cm) with F_4 treatment and the minimum (52.44cm) was obtained from the F_1 treatment. The results indicated that 100 ppm zinc helps to increase spread of plant similar findings also reported by Batesi *et al*. (1979) and Singh and Singh (2004) from an experiment.

Mulching showed significant variation in terms of spread of plant at 30, 45, 60 DAT. The maximum (35.13cm) spread of plant was recorded from black polythene mulch (M_3) which was closely followed (32.31cm) by M_2 as white polythene mulch and the minimum (27.95cm) was from control i.e. no mulch at 30 DAT (Figure 5). At 45 DAT the maximum (55.91 cm) spread of plant was found from M_3 which was followed (52.86 cm) by M_2 treatment, while the minimum (48.43 cm) was from the control. The maximum (56.48 cm) spread of plant was recorded from the treatment of M_3 closely followed (54.35 cm) by M_2 and the minimum (51.16 cm) from the control at 60 DAT. From the results it was found that mulching increase the spread of plant and black polythene mulch was better than the white polythene mulch under the present experiment. Benoit and Ceustermans (1990) also found the similar findings from their experiment earlier but this finding is not supported by the findings of Bragagnolo and Mielriezuk (1990); Farooque and Mondal (1987) and Shoemaker (1947).

The spread of plant significantly varied due to the interaction effect of zinc and mulch. The maximum (36.40cm) spread of plant was recorded at 30 DAT from the combined effect of F_3M_3 (Zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (Zinc 0 ppm + no mulch) gave the minimum (22.93 cm) spread of plant (Table 1). At 45 DAT significant variations in terms of spread of plant was also observed among the treatments and maximum (58.53 cm) spread

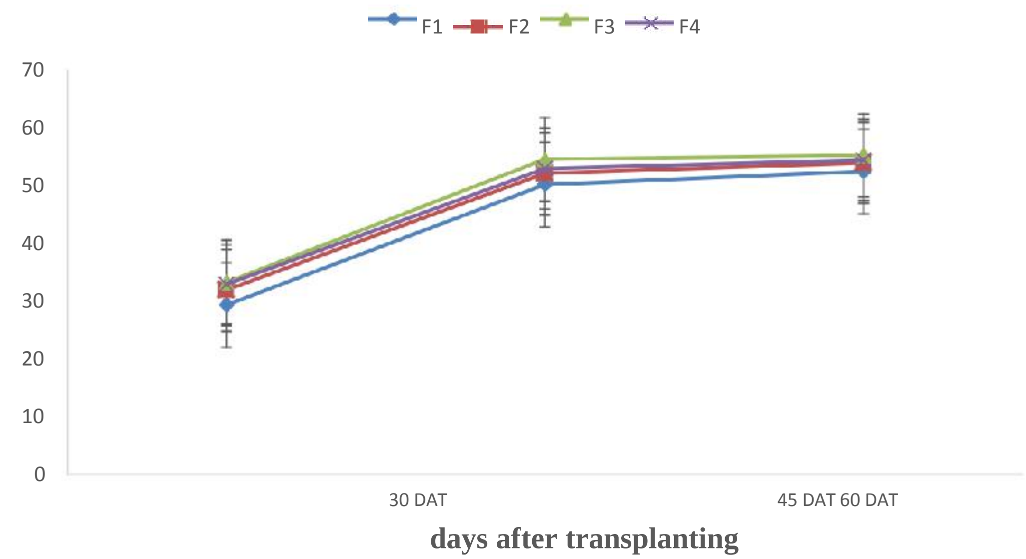


Fig 4. Effect of zinc on spread of plant at different days after transplanting of red cabbage (LSD at 5% level)

F_1= No zinc (Control), F_2=50 ppm zinc, F_3=100 ppm zinc, F_4=150 ppm zinc

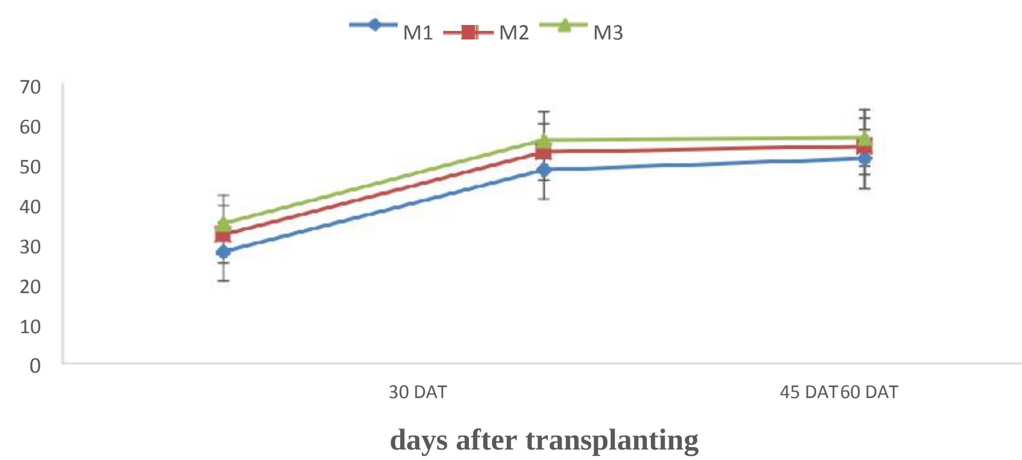


Fig 5 : Effect of mulch materials on spread of plant at different days after transplanting of red cabbage (LSD at 5% level)

M_1=No mulch (Control), M_2=White polythene mulch, M_3=Black Polythene

of plant was observed from the treatment combination of F_3M_3 whereas the minimum (44.53cm) was recorded from F_1M_1 (Table 2). At 60 DAT the maximum (57.60 cm) spread of plant was recorded from the treatment combination of F_3M_3 and the minimum (48.33 cm) was recorded from F_1M_1. From the results it was revealed that 100 ppm zinc with black polythene mulch favored the spread of plant. With the higher zinc and mulching ensured the favorable condition and the ultimate results maximum photosynthesis as well as maximum spread of plant.

4.3 Number of leaves per plant:

Statistically significant difference was recorded in number of unfolded leaves per plant due to the different plant spacing at 30, 45, and 60 DAT and (Appendix VI-VIII). Treatment F_3 gave the maximum (10.23) number of leaves per plant at 30 DAT which was statistically similar (9.81) with F_4, while the treatment F_1 gave the minimum (8.73). The maximum (13.32) number of leaves per plant was observed from treatment F_3 which was statistically identical (13.05) with F_2 treatment and the minimum (12.35) was found from the F_1 treatment at 45 DAT (Figure 6). At 60 DAT the maximum (17.51) number of leaves per plant was recorded from the treatment F_3 which was closely followed (17.25) with F_4 treatment and the minimum (16.64) was from the F_1 treatment. The results indicated that 100ppm zinc helps to increase number of leaves per plant.

Number of leaves per plant at 30, 45, 60 DAT showed significant differences for different mulching. The maximum (11.11) number of unfolded leaves per plant was recorded in from black polythene mulch for treatment M_3 which was statistically identical (9.67) with M_2 as white polythene mulch and the minimum (7.92) was from control i.e. no mulch at 30 DAT (Figure 7). At 45 DAT the maximum (13.93) number of leaves per plant was found from M_3 followed by (12.90) M_2 treatment, while the minimum (11.76) was from control treatment. The maximum (18.01) number of leaves per plant was recorded from M_3 treatment which was closely (17.09) followed by M_2 and the minimum was

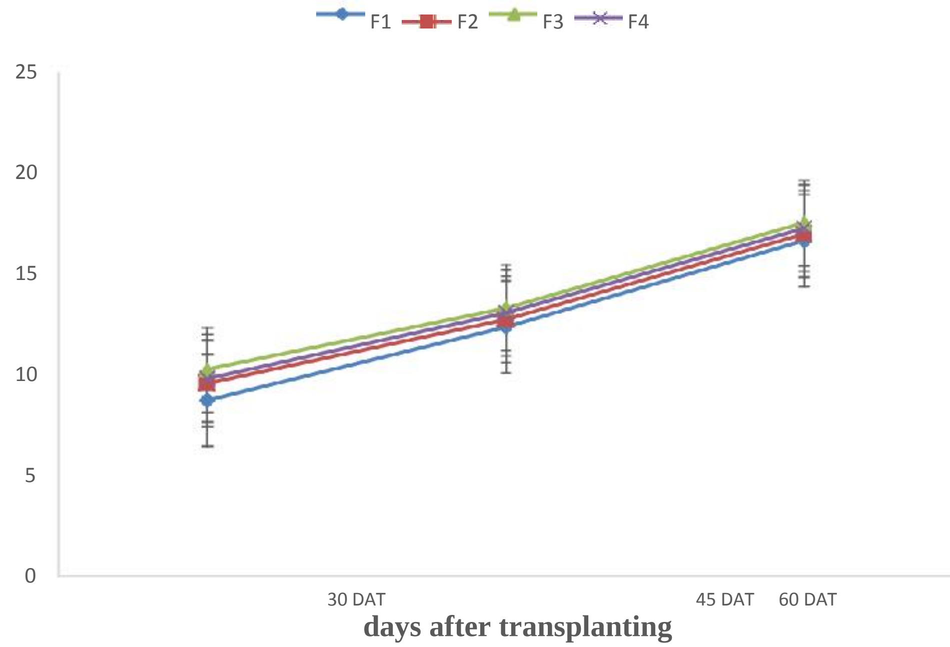


Fig 6: Effect of zinc on number of leaves per plant at different days after transplanting of red cabbage (LSD at 5% level)

F_1= No zinc (Control), F_2=50 ppm zinc, F_3=100 ppm zinc, F_4=150 ppm zinc

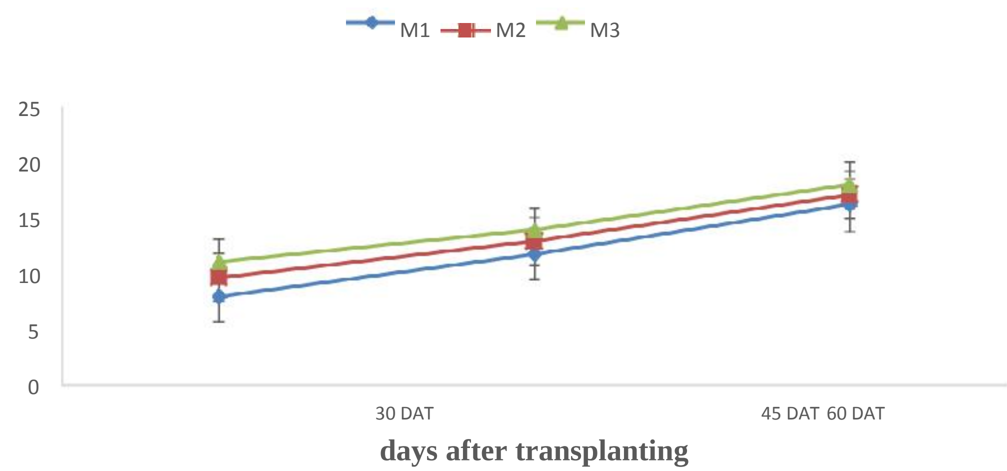


Fig 7: Effect of mulch materials on number of leaves per plant at different day after transplanting of red cabbage (LSD at 5% level)

M_1=No mulch (Control), M_2=White polythene mulch, M_3=Black Polythene

Table 2. Interaction effect of zinc and mulch materials on number of leaves and Leaf length/plant of Red cabbage

Treatment combination	No of leaves			Leaf length(cm)		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
F_1M_1	6.60 j	10.97 g	15.53 g	14.00 g	26.20 f	31.13 h
F_1M_2	9.07 f-h	12.50 e	16.80 c-f	17.40 e	29.47 b-e	32.47 ef
F_1M_3	10.53 b-d	13.60 bc	17.60 a-d	18.87 bc	30.70 a-c	34.13 c
F_2M_1	8.17 i	11.80 f	16.13 fg	15.67 f	27.73 ef	31.47 gh
F_2M_2	9.57 e-g	12.67 de	16.97 c-f	17.67 de	29.67 b-d	32.67 ef
F_2M_3	11.00 a-c	13.73 bc	17.80 a-c	19.20 bc	30.87 a-c	34.87 b
F_3M_1	8.80 g-i	12.27 ef	16.60 d-f	16.93 e	29.13 c-e	32.27 ef
F_3M_2	10.23 c-e	13.30 cd	17.40 b-e	18.67 bc	30.53 a-d	33.47 cd
F_3M_3	11.67 a	14.40 a	18.53 a	20.33 a	32.07 a	36.20 a
F_4M_1	8.40 hi	12.03 ef	16.43 e-g	16.00 f	28.73 de	32.00 fg
F_4M_2	9.80 d-f	13.13 cd	17.20 b-e	18.33 cd	30.33 a-d	32.93 de
F_4M_3	11.23 ab	14.00 ab	18.13 ab	19.40 b	31.07 ab	35.20 b
S.E	0.27	0.20	0.30	0.28	0.56	0.23
Significance level	0.00	0.00	0.00	0.00	0.00	0.00

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.

S.E=Standard Error

F_1= No zinc (control) — M_1=No mulch (control)

F_2=50 ppm zinc — M_2=White polythene mulch

F_3=100 ppm zinc — M_3=Black Polythene mulch

F_4=150 ppm zinc

(16.17) from the control at 60 DAT. From the results it was found that mulching increased the number of leaves per plant and black polythene mulch was better than the white polythene mulch.

Interaction effect of zinc and mulch significantly differs in terms of number of leaves per plant under the present trial. The maximum (11.67) number of leaves per plant was recorded at 30 DAT from the combined effect of F_3M_3 (Zinc 100ppm + black polythene mulch, while the treatment F_1M_1 (Zinc 0 ppm + no mulch) gave the minimum (6.60) number of leaves per plant (Table 2). At 45 DAT the maximum (14.40) number of leaves per plant was observed from the treatment combination.F_3M_3 whereas the minimum (10.96) was recorded from F_1M_1. At 60 DAT the maximum (18.53) number of leaves per plant was recorded from the treatment combination of F_3M_3 and the minimum (15.53) was recorded from the F_1M_1. From the results it was revealed that 100ppm zinc with black polythene mulch ensure maximum vegetative growth as well as number of leaves per plant.

4.4 Leaf length (cm):

A statistically significant variation was recorded in terms of Leaf length due to the different level of zinc at 30, 45, 60 DAT (Appendix IX-XI). Zinc 100 ppm treatment (F_3) gave the maximum (18.64 cm) Leaf length at 30 DAT which was closely followed (17.91 cm) with F_4 treatment at 150 ppm zinc, while 0 ppm zinc as treatment F_1 gave the minimum (16.75 cm). The maximum (30.57 cm) length of leaf was observed from treatment F_3 which was statistically identical (30.04 cm) with F_4 treatment and the minimum (28.78 cm) was found from the F_1 treatment at 45 DAT (Figure 8). At 60 DAT the maximum (33.97 cm) length of leaf was recorded from the treatment F_3 which was statistically identical (33.37 cm) with F_4 treatment and the minimum (32.57 cm) was obtained from the F_1 treatment. The results indicated that 100 ppm zinc helps to increase leaf length. Similar findings also reported by Sivakumar *et al*. (2005) from an experiment.

Mulching showed significant variation in terms of leaf length of plant at 30, 45, 60 DAT. The maximum (19.45 cm) leaf length was recorded from black

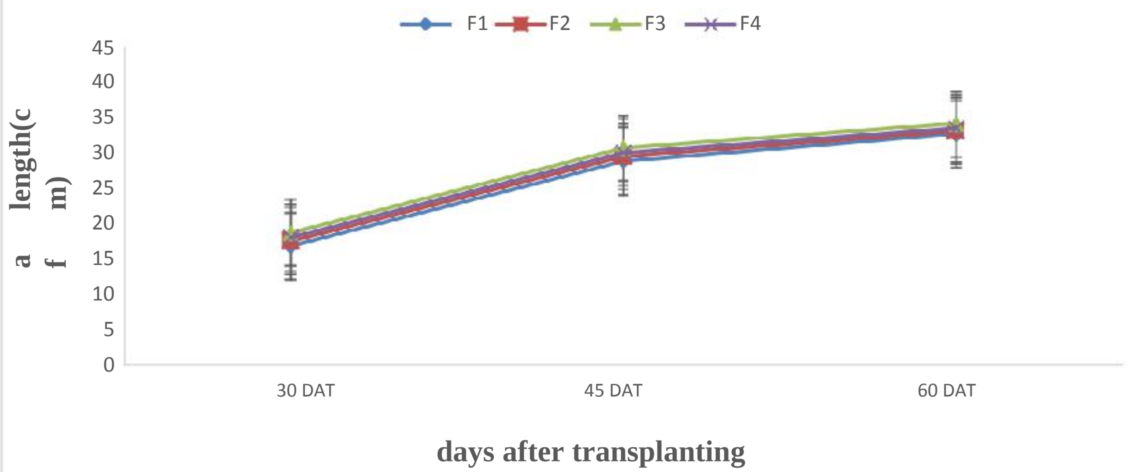


Fig 8: Effect of zinc on leaf length at different days after

F_1= No zinc (Control), F_2=50 ppm zinc, F_3=100 ppm zinc F_4=150 ppm zinc

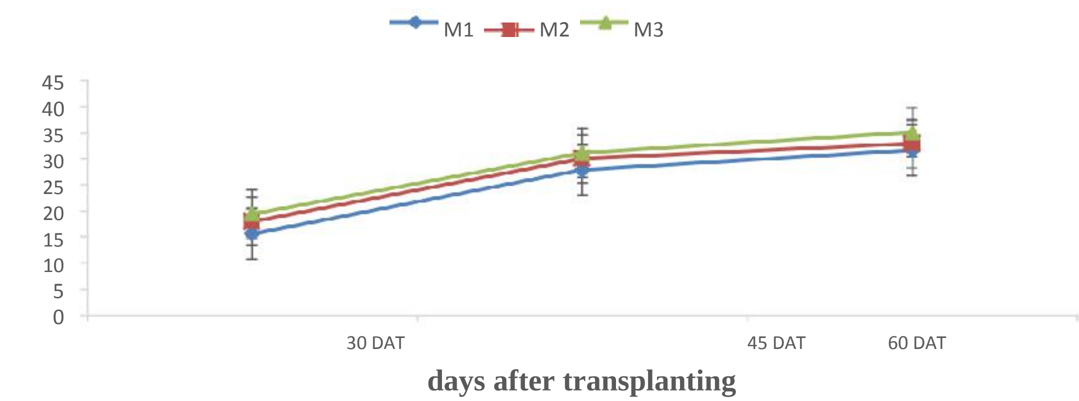


Fig 9: Effect of mulch materials on leaf length at different days after transplanting of red cabbage (LSD at 5% level)

M_1=No mulch (Control), M_2=White polythene mulch, M_3=Black Polythene

polythene mulch (M_3) which was closely followed (18.01 cm) by M_2 as white polythene mulch and the minimum (15.65 cm) was from control i.e. no mulch at 30 DAT (Figure 9).At 45 DAT the maximum (31.17 cm) leaf length was found from M_3 which was followed (30.00 cm) by M_2 treatment, while the minimum (27.95cm) was from the control. The maximum (35.10cm) leaf length was recorded from the treatment of M_3 closely followed (32.88cm) by M_2 and the minimum (31.71 cm) from the control at 60 DAT. From the results it was found that mulching increase leaf length. Black polythene mulch was better than the white polythene mulch under the present experiment.

Leaf length significantly varied due to the interaction effect of zinc and mulch. The maximum (20.33 cm) leaf length was recorded at 30 DAT from the combined effect of F_3M_3 (Zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (Zinc 0 ppm+ no mulch) gave the minimum (14.00cm) leaf length (Table 2). At 45 DAT significant variations in terms of leaf length was also observed among the treatments and the maximum (32.06 cm) leaf length was observed from the treatment combination of F_3M_3 whereas the minimum (26.20 cm) was recorded from F_1M_1 (Table 2). At 60 DAT the maximum

(36.20cm) leaf length was recorded from the treatment combination of F_3M_3 and the minimum (31.13cm) was recorded from F_1M_1- From the results it was revealed that 100 ppm Zinc with black polythene mulch favored the leaf length and mulching ensured the favorable condition and the ultimate results maximum photosynthesis as well as maximum leaf length.

4.5 Leaf breadth (cm):

A statistically significant variation was recorded in terms of leaf breadth due to the different level of zinc at 30, 45, 60 DAT (Appendix XII-XIV). Zinc 100 ppm treatment (F_3) gave the maximum (10.62 cm) leaf breadth at 30 DAT which was closely followed (10.17 cm) with F_4 treatment at 150 ppm zinc, while 0 ppm zinc as treatment F_1 gave the minimum (9.13cm). The maximum (21.17 cm) breadth of leaf was observed from treatment F_3 which was statistically identical (20.41

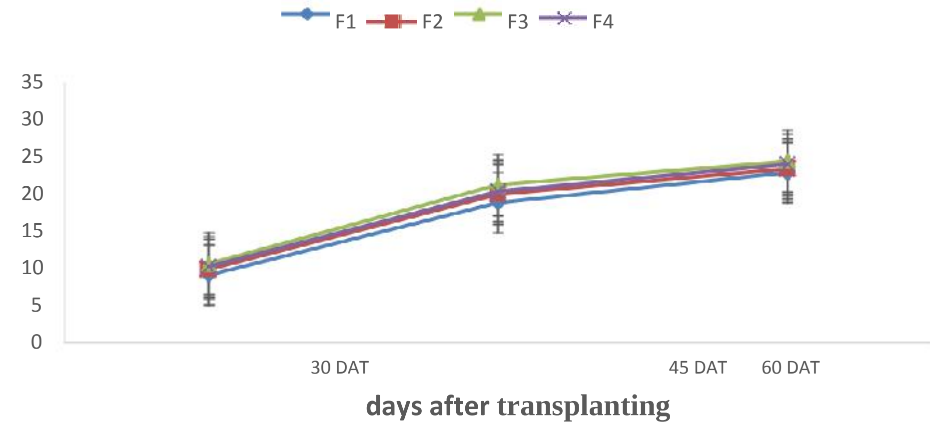


Fig 10: **Effect of zinc on leaf breadth at different days after transplanting of red cabbage (LSD at 5% level)**

F_1= No zinc (Control), F_2=50 ppm zinc, F_3=100 ppm zinc.F_4=150 ppm zinc

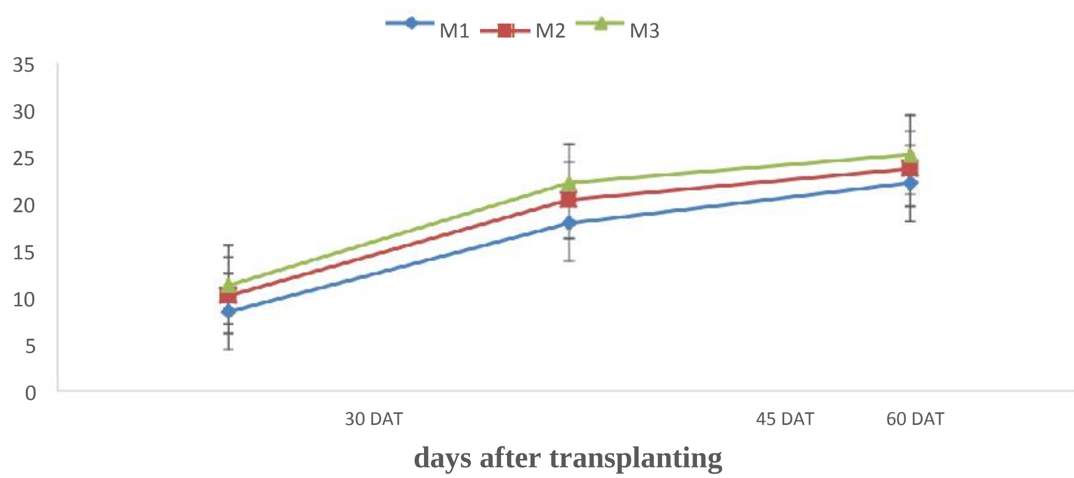


Fig 11: **Effect of mulch materials on leaf breadth at different days after transplanting of red cabbage (LSD at 5% level)**

M_1=No mulch (Control), M_2=White polythene mulch, M_3=Black Polythene

cm) with F_4 treatment and the minimum (18.84 cm) was found from the F_1 treatment at 45 DAT (Figure 10). At 60 DAT the maximum (24.42 cm) breadth of leaf was recorded from the treatment F_3 which was statistically identical (23.91 cm) with F_4 treatment and the minimum (22.84 cm) was obtained from the F_1 treatment. The results indicated that 100 ppm zinc helps to increase leaf breadth.

Mulching showed significant variation in terms of leaf breadth at 30, 45, 60 DAT. The maximum (11.26 cm) leaf breadth was recorded from black polythene mulch (M_3) which was closely followed (10.11 cm) by M_2 as white polythene mulch and the minimum (8.43 cm) was from control i.e. no mulch at 30 DAT (Figure 11). At 45 DAT the maximum (22.10 cm) leaf breadth was found from M_3 which was followed (20.29 cm) by M_2 treatment, while the minimum (17.86cm) was from the control. The maximum (25.15cm) leaf breadth was recorded from the treatment of M_3 closely followed (23.65cm) by M_2 and the minimum (22.11 cm) from the control at 60 DAT. From the results it was found that mulching increase leaf breadth. Black polythene mulch was better than the white polythene mulch under the present experiment.

Leaf breadth significantly varied due to the interaction effect of zinc and mulch. The maximum (11.93 cm) leaf breadth was recorded at 30 DAT from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (zinc 0 ppm+ no mulch) gave the minimum (6.93cm) Leaf breadth (Table 3). At 45 DAT significant variations in terms of leaf breadth was also observed among the treatments and the maximum (23.46 cm) leaf breadth was observed from the treatment combination of F_3M_3 whereas the minimum (15.53cm) was recorded from F_1M_1 (Table 2). At 60 DAT the maximum

(26.60cm) leaf breadth was recorded from the treatment combination of F_3M_3 and the minimum (21.46cm) was recorded from F_1M_1, from the results it was revealed that 100 ppm zinc with black polythene mulch favored the leaf breadth and mulching ensured the favorable condition and the ultimate results maximum photosynthesis as well as maximum leaf breadth.

Table 3. Interaction effect of different level of zinc and mulch materials on leaf breadth and total plant weight of red cabbage

Treatment combination	Breadth(cm)			No. of unfolded leaves
	30 DAT	45 DAT	60 DAT	
F_1M_1	6.93 h	15.53 g	21.46 f	7.86 g
F_1M_2	9.66 e	19.73 c-f	23.26 c-e	8.46 d-f
F_1M_3	10.80 bc	21.26 bc	23.80 c-e	8.86 b-d
F_2M_1	8.53 g	18.00 f	22.06 ef	8.00 g
F_2M_2	9.86 de	20.20 c-e	23.46 c-e	8.56 d-f
F_2M_3	11.06 b	21.53 bc	24.60 bc	9.06 a-c
F_3M_1	9.33 ef	19.20 d-f	22.60 d-f	8.26 e-g
F_3M_2	10.60 bc	20.86 b-d	24.06 b-d	8.80 cd
F_3M_3	11.93 a	23.46 a	26.60 a	9.46 a
F_4M_1	8.93 fg	18.73 ef	22.33 d-f	8.20 fg
F_4M_2	10.33 cd	20.36 b-e	23.80 c-e	8.70 c-e
F_4M_3	11.26 b	22.13 ab	25.60 ab	9.26 ab
S.E	0.21	0.58	0.54	0.14
Significance level	0.00	0.00	0.00	0.00

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.

S.E=Standard Error

F_1= No zinc (control)

F_2=50 ppm zinc

F_3=100 ppm zinc

F_4=150 ppm zinc

M_1=No mulch (control)

M_2=White polythene mulch

M_3=Black Polythene mulch

4.6 Total weight of plant (g):

A significant variation was recorded in terms of fresh weight of total plant due to the different level of zinc at harvest (Appendix XX). Treatment F3 gave the maximum (1346.68 g) fresh weight of total plant which was statistically similar (1323.33gm) with F_4 treatment (zinc 150 ppm), while(0 ppm) zinc F_1 gave the minimum (1231.88 g) (Table 4).

Fresh weight of total plant at harvest showed a significant variation was recorded for using different mulch material. The maximum (1408.10g) fresh weight of total plant was recorded from black polythene mulch (M_3) which was closely followed (1306.36) by M_2 (white polythene mulch) and the minimum (1165.00) was from control i.e. no mulch. From the results it was found that mulching increase the fresh weight of total plant and black polythene mulch was better than the white polythene mulch (Table 4).

Interaction effect of zinc and mulch showed significant variation in terms of fresh weight of head under the present trial. The maximum (1447.067) fresh weight of head was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (zinc 0 ppm+ no mulch) gave the minimum (1052.60) fresh weight of total plant under the present trial (Table 5).

4.7 Fresh weight of unfolded leaves per plant (gm):

A significant variation was recorded in terms of fresh weight of unfolded leaves per plant due to the different level of zinc at harvest (Appendix XIX). Treatment F_3 gave the maximum (386.40 g) fresh weight of unfolded leaves per plant which was statistically similar (373.33 g) with F_4 treatment (zinc 150 ppm) and the minimum (352.93g) was found from F_1 (Table 4). Fresh weight of unfolded leaves per plant at harvest showed significant variation was recorded for using different mulch material. The maximum (403.80g) fresh weight of unfolded leaves per plant was recorded from black polythene mulch (M_3) which was

Table 4. Effect of different level of zinc and mulch materials on yield contributing characters of red cabbage

Treatment	No. of unfolded leaves	Fresh wt. of unfolded leaves(g)	Total plant wt.(g)	Head wt.(g)	Dry matter content of head (%)	Stem length(cm)
Zinc						
F_1	8.40 c	352.93 c	1231.88 b	794.35 b	9.17 c	4.80 c
F_2	8.54 bc	361.46 bc	1270.71 b	866.84 a	9.35 bc	4.94 bc
F_3	8.84 a	386.40 a	1346.68 a	906.08 a	10.14 a	5.27 a
F_4	8.72 ab	373.33 ab	1323.33 a	896.86 a	9.60 b	5.16 ab
Standard Error	0.08	4.86	15.87	15.21	0.11	0.10
Significance level	0.30	0.17	0.17	0.09	0.09	0.25
Mulching						
M_1	8.08 c	335.28 c	1165.00 c	757.86 c	8.85 c	4.49 c
M_2	8.63 b	366.51 b	1306.36 b	880.76 b	9.38 b	5.12 b
M_3	9.16 a	403.80 a	1408.10a	959.48 a	10.45 a	5.51 a
Standard Error	0.07	4.21	13.74	13.17	0.10	0.09
Significance level	0.00	0.00	0.00	0.00	0.00	0.00

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.

S.E=Standard Error

F_1= No zinc (control)

F_2=50 ppm zinc

F_3=100 ppm zinc

F_4=150 ppm zinc

M_1=No mulch (control)

M_2=White polythene mulch

M_3=Black Polythene mulch

Table 5. Interaction effect of different level of zinc and mulch materials on yield contributing characters of red cabbage

Treatment combination	Fresh wt. of unfolded leaves(g)	Total wt. of plant(g)	Head wt.(g)	Dry matter content of head (%)	Stem length(cm)
F_1M_1	315.20 h	1052.60 f	627.46 h	8.61 g	4.13 e
F_1M_2	358.86 d-f	1277.73 c-e	847.13 d-g	9.14 d-g	4.97 bc
F_1M_3	384.73 b-d	1365.33 a-c	908.46 b-d	9.76 b-d	5.32 a-c
F_2M_1	327.86 gh	1126.26 f	773.53 g	8.79 fg	4.28 de
F_2M_2	363.86 d-f	1292.53 c-e	872.33 c-f	9.35 c-f	5.06 bc
F_2M_3	392.67 bc	1393.33 ab	954.66 a-c	9.91 bc	5.47 ab
F_3M_1	351.86 e-g	1254.06 de	822.06 e-g	9.07 e-g	4.84 c
F_3M_2	378.26 c-e	1338.93 b-d	900.40	9.57 c-e	5.24 a-c
F_3M_3	429.06 a	1447.06 a	995.80 a	11.790 a	5.73 a
F_4M_1	346.20 fg	1227.06 e	808.40 fg	8.95 e-g	4.72 cd
F_4M_2	365.06 d-f	1316.26 b-d	903.20 b-e	9.49 c-e	5.22 a-c
F_4M_3	408.73 ab	1426.67 a	979.00 ab	10.36 b	5.54 ab
S.E	8.43	27.49	26.34	0.20	0.18
Significance level	0.00	0.00	0.00	0.00	0.00

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.

S.E=Standard Error

F_1= No zinc (control) M_1=No mulch (control)

F_2=50 ppm zinc M_2=White polythene mulch

F_3=100 ppm zinc M_3=Black Polythene mulch

F_4=150 ppm zinc

closely followed (366.51 g) by M_2 (white polythene mulch) and the minimum (335.28 g) was from control i.e. no mulch. From the results it was found that mulching increase the fresh weight of unfolded leaves per plant and black polythene mulch was better than the white polythene mulch (Table 4).

Interaction effect of zinc and mulch showed significant variation in terms of fresh weight of unfolded leaves per plant. The maximum (429.06 g) fresh weight of unfolded leaves per plant was recorded from combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (zinc 0 ppm + no mulch) gave the minimum (315.20g) fresh weight of unfolded leaves per plant (Table 5).

4.8 Number of unfolded leaves:

A significant variation was recorded in terms of no. of unfolded leaves per plant due to the different level of zinc at harvest (Appendix XVIII). Treatment F_3 gave the maximum (8.84) no. of unfolded leaves per plant which was statistically similar (8.72) with F_4 treatment (zinc 150 ppm) and the minimum (8.40) was found from F_1 (Table 4). No of unfolded leaves per plant at harvest showed significant variation was recorded for using different mulch material. The maximum (9.16) No of unfolded leaves per plant was recorded from black polythene mulch (M_3) which was closely followed (8.63) by M_2 (white polythene mulch) and the minimum (8.08) was from control i.e. no mulch. From the results it was found that mulching increase the no. of unfolded leaves per plant and black polythene mulch was better than the white polythene mulch (Table 4).

Interaction effect of zinc and mulch showed significant variation in terms of No. of unfolded leaves per plant. The maximum (9.46) no. of unfolded leaves per plant was recorded from combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (zinc 0 ppm + no mulch) gave the minimum (7.86) no. of unfolded leaves per plant (Table 3).

4.9 Fresh weight of head (g)

A significant variation was recorded in terms of fresh weight of head per plant due to the different level of zinc at harvest (Appendix XXI). Treatment F_3 gave the maximum (906.08g) fresh weight of head per plant which was statistically similar (896.86g) with F_4 treatment (zinc 150 ppm) and the minimum (794.35g) was found from F_1 (Table 4). Fresh weight of head per plant at harvest showed significant variation was recorded for using different mulch material. The maximum (959.48g) fresh weight of head per plant was recorded from black polythene mulch (M_3) which was closely followed (880.76g) by M_2 (White polythene mulch) and the minimum (757.86g) was from control i.e. no mulch. From the results it was found that mulching increase the fresh weight of head per plant and black polythene mulch was better than the white polythene mulch (Table 4).

Interaction effect of zinc and mulch showed significant variation in terms of fresh weight of head per plant. The maximum (995.80g) fresh weight of head per plant was recorded from combined effect of F_3M_3 (Zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (zinc 0 ppm + no mulch) gave the minimum (627.46g) fresh weight of head per plant (Table 5).

4.10 Dry matter content of head (%)

A statistically non-significant variation was recorded in terms of dry matter content of head due to the different level of zinc at harvest (Appendix XXII). Zinc 100 ppm (F_3) gave the maximum (10.15%) dry matter content of head (Table 4), while 0 ppm zinc as treatment F_1 showed the minimum (9.17%).

Dry matter content of head at harvest showed a significant variation was recorded for the application of different mulch materials. The maximum (10.45%) dry matter content of head was recorded from black polythene mulch (M_3) which was followed (9.38%) by M_2 (white polythene mulch) and the minimum (8.85%) was from control i.e. no mulch. Hembry *et al*. (1994) recorded the similar trend of results. From the results it was found that mulching increase

627.46g	**847.13g**	**908.46g**	**773.53g**	**872.33g**	**954.66g**	**822.06g**	**900.40g**	**995.80g**	**808.40g**	**903.20g**	**979.00g**

F_1M_1	F_1M_2	F_1M_3	F_2M_1	F_2M_2	F_2M_3	F_3M_1	F_3M_2	F_3M_3	F_4M_1	F_4M_2	F_4M_3

Plate 8: Effect of zinc and mulching on head weight of red cabbage

the dry matter content of head and black polythene mulch was better than the white polythene mulch (Table 4).

Interaction effect of zinc and mulch showed significant variation in terms of dry matter content of head under the present trial. The maximum (11.79%) dry matter content of head was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while F_1M_1 (zinc 0 ppm + no mulch) gave the minimum (8.61%) dry matter content of head (Table 5).

4.11 Length of stem (cm)

A statistically significant variation was recorded in terms of length of stem due to the different level of zinc at harvest (Appendix XXIII). Treatment F_3 gave the longest (5.27 cm) length of stem which was statistically similar (5.16 cm) with F_4 treatment (zinc 150 ppm), while F_1 treatment gave the shortest (4.80 cm) (table 4) .Length of stem at harvest showed a significant variation was recorded for different mulching. The longest (5.51 cm) length of stem was recorded from black polythene mulch for treatment M_3 which was closely followed (5.12 cm) by M_2 and the shortest (4.49 cm) length was from control i.e. no mulch. From the results it was found that mulching increase the length of stem and black polythene mulch was better than the white polythene mulch (Table 4).

Interaction effect of zinc and mulch showed significant variation in terms of length of stem under the present trial. The longest (5.73 cm) length of stem was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment combination of F_1M_1 (zinc o ppm + no mulch) gave the shortest (4.13 cm) length of stem (Table 5).

4.12 Stem diameter (cm):

A statistically significant variation was recorded in terms of diameter of stem due to the different level of zinc at harvest (Appendix XXIV). Treatment F_3 gave the maximum (2.77cm) diameter of stem which was statistically similar (2.75 cm) with F_4 treatment (zinc 150 ppm), while F_1 treatment gave the minimum (2.66 cm).

Table 6. Effect of different level of zinc and mulch materials on yield contributing characters of red cabbage

Treatment	Stem diameter(cm)	Root length(cm)	Thickness of head (cm)	Head diameter(cm)
Zinc				
F_1	2.66 b	15.77 b	12.69 c	11.62 c
F_2	2.71 ab	16.12 ab	13.05 ab	11.90 bc
F_3	2.77 a	16.70 a	13.41 a	12.34 a
F_4	2.75 b	16.27 ab	13.28 a	12.03 ab
S.E	0.02	0.22	0.17	0.12
Significance level	0.35	0.34	0.24	0.24
Mulching				
M_1	2.58 c	15.24 c	12.38 c	11.19 c
M_2	2.73 b	16.14 b	13.11 b	12.01 b
M_3	2.86 a	17.29 a	13.83 a	12.72 a
S.E	0.02	0.19	0.14	0.10
Significance level	0.00	0.00	0.00	0.00

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.

S.E=Standard Error

F_1= No zinc (control)

F_2=50 ppm zinc

F_3=100 ppm zinc

F_4=150 ppm zinc

M_1=No mulch (control)

M_2=White polythene mulch

M_3=Black Polythene mulch

Table 7. Interaction effect of different level of zinc and mulch materials on yield contributing characters of red cabbage

Treatment combination	Stem diameter(cm)	Root length(cm)	Thickness of head(cm)	Head diameter(cm)
F_1M_1	2.49 f	14.43 f	11.82 e	10.59 g
F_1M_2	2.69 d-f	15.92 c-e	12.79 cd	11.75 d-f
F_1M_3	2.81 a-d	16.97 a-d	13.47 a-c	12.51 a-c
F_2M_1	2.57 ef	15.27 ef	12.28 de	11.14 fg
F_2M_2	2.73 c-e	16.00 b-e	13.10 b-d	11.97 c-e
F_2M_3	2.85 a-c	17.11 a-c	13.77 ab	12.59 a-c
F_3M_1	2.65 ef	15.75 de	12.73 c-e	11.64 ef
F_3M_2	2.77 a-e	16.53 b-e	13.29 a-c	12.320b-d
F_3M_3	2.91 a	17.84 a	14.19 a	13.06 a
F_4M_1	2.62 e-g	15.49 ef	12.68 c-e	11.37 ef
F_4M_2	2.75 b-e	16.10 b-e	13.25 a-c	12.02 c-e
F_4M_3	2.89 ab	17.22 ab	13.90 ab	12.71 ab
S. E	0.05	0.33	0.29	0.21
Significance level	0.00	0.00	0.00	0.00

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.

S.E=Standard Error

F_1= No zinc (control) M_1=No mulch (control)

F_2=50 ppm zinc M_2=White polythene mulch

F_3=100 ppm zinc M_3=Black Polythene mulch

F_4=150 ppm zinc

Diameter of stem at harvest showed a significant variation was recorded for different mulching. The maximum (2.86 cm) diameter of stem was recorded from black polythene mulch for treatment M_3 which was closely followed (2.73 cm) by M_2 and the minimum (2.58 cm) diameter was from control i.e. no mulch. From the results it was found that mulching increase the diameter of stem and black polythene mulch was better than the white polythene mulch (Table 6).

Interaction effect of zinc and mulch showed significant variation in terms of diameter of stem under the present trial. The maximum (2.91cm) diameter of stem was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment combination of F_1M_1 (zinc o ppm + no mulch) gave the minimum (2.49cm) diameter of stem (Table 7).

4.13 Root length (cm):

A statistically significant variation was recorded in terms of length of root due to the different level of zinc at harvest (Appendix XXV). Treatment F_3 gave the longest (16.70cm) length of root which was statistically similar (16.27 cm) with F_4 treatment (zinc 200 ppm), while F_1 treatment gave the shortest (15.77 cm).

Length of root at harvest showed a significant variation was recorded for different mulching. The longest (17.29 cm) length of root was recorded from black polythene mulch for treatment M_3 which was closely followed (16.14 cm) by M_2 and the shortest (15.24 cm) length was from control i.e. no mulch. From the results it was found that mulching increase the length of root and black polythene mulch was better than the white polythene mulch (Table 6).

Interaction effect of zinc and mulch showed significant variation in terms of length of root under the present trial. The longest (17.84 cm) length of root was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment combination of F_1M_1 (zinc o ppm + no mulch) gave the shortest (14.43 cm) length of root (Table 7)

4.14 Thickness of head (cm):

A statistically significant variation was recorded in terms of thickness of head due to the different level of zinc at harvest (Appendix XXVI). Treatment F_3 gave the maximum (13.41cm) thickness of head which was statistically similar (13.28 cm) with F_4 treatment (zinc 150 ppm), while F_1 treatment gave the minimum (12.69cm) (Table 6)

Thickness of head at harvest showed a significant variation was recorded for different mulching. The maximum (13.83 cm) thickness of head was recorded from black polythene mulch for treatment M_3 which was closely followed (13.11 cm) by M_2 and the minimum (12.38cm) thickness was from control i.e. no mulch. From the results it was found that mulching increase the thickness of head and black polythene mulch was better than the white polythene mulch (Table 6).

Interaction effect of zinc and mulch showed significant variation in terms of thickness of head under the present trial. The maximum (14.19cm) thickness of head was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment combination of F_1M_1 (zinc o ppm + no mulch) gave the minimum (11.82cm) thickness of head (Table 7).

4.15 Diameter of head (cm):

A statistically significant variation was recorded in terms of diameter of head due to the different level of zinc at harvest (Appendix XXVII). Treatment F_3 gave the maximum (12.34 cm) diameter of head which was statistically similar (12.03 cm) with F_4 treatment (zinc 200 ppm), while F_1 treatment gave the minimum (11.62cm) (Table 6).

Diameter of head at harvest showed a significant variation was recorded for different mulching. The maximum (12.72 cm) diameter of head was recorded from black polythene mulch for treatment M_3 which was closely followed (12.01 cm) by M_2 and the minimum (11.19 cm) diameter was from control i.e. no mulch. From the results it was found that mulching increase the diameter of head and black polythene mulch was better than the white polythene mulch (Table 6).

Table 8. Effect of different level of zinc and mulch materials on yield contributing characters of red cabbage

Treatment	Gross yield per plant(g)	Gross yield Per plot(g)	Gross yield per ha(t/ha)	Marketable yield per plot(g)	Marketable Yield per ha(t/ha)
Zinc					
F_1	1147.29 c	13767.47 c	57.36 c	9532.27 b	39.72 b
F_2	1228.31 b	14739.73 b	61.42 b	10402.13 a	43.34 a
F_3	1292.49 a	15509.87 a	64.62 a	10873.07 a	45.30 a
F_4	1270.20 ab	15242.40 ab	63.51 ab	10762.40 a	44.84 a
S.E	16.56	198.70	0.83	182.55	0.76
Significance level	0.10	0.10	0.10	0.09	0.09
Mulching					
M_1	1093.15 c	13117.80 c	54.66 c	9094.40 c	37.89 c
M_2	1247.28 b	14967.40 b	62.36 b	10569.20 b	44.04 b
M_3	1363.28 a	16359.40 a	68.16 a	11513.80 a	47.97 a
S.E	14.34	172.08	0.72	158.09	0.66
Significance level	0.00	0.00	0.00	0.00	0.00

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.

S.E=Standard Error

F_1= No zinc (control) M_1=No mulch (control)

F_2=50 ppm zinc M_2=White polythene mulch

F_3=100 ppm zinc M_3=Black Polythene mulch

F_4=150 ppm zinc

Table 9. Interaction effect of different level of zinc and mulch materials on yield contributing characters of Red cabbage

Treatment combination	Gross yield per plant(g)	Gross yield per plot(g)	Gross yield per ha(t/ha)	Marketable yield per plot(g)	Marketable yield per ha(t/ha)
F_1M_1	942.67 f	11312.00 f	47.13 f	7529.60 h	31.37 h
F_1M_2	1206.00 cd	14472.00 cd	60.30 cd	10165.60 d-g	42.36 d-g
F_1M_3	1293.200bc	15518.40 bc	64.66 bc	10901.60 b-d	45.42 b-d
F_2M_1	1101.40 e	13216.80 e	55.07 e	9282.40 g	38.67 g
F_2M_2	1236.20 cd	14834.40 cd	61.81 cd	10468.00 c-f	43.62 c-f
F_2M_3	1347.33 ab	16168.00 ab	67.37 ab	11456.00 a-c	47.73 a-c
F_3M_1	1173.93 de	14087.20 de	58.69 de	9864.80 e-g	41.10 e-g
F_3M_2	1278.67 bc	15344.00 bc	63.93 bc	10804.80 b-e	45.02 b-e
F_3M_3	1424.87 a	17098.40 a	71.24 a	11949.60 a	49.79 a
F_4M_1	1154.60 de	13855.20 de	57.73 de	9700.80 fg	40.42 fg
F_4M_2	1268.27 bc	15219.20 bc	63.41 bc	10838.40 b-e	45.16 b-e
F_4M_3	1387.73 a	16652.80 a	69.39 a	11748.00 ab	48.95 ab
S.E	28.68	344.16	1.43	316.19	1.32
Significance level	0.00	0.00	0.00	0.00	0.00

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.

S.E=Standard Error

F_1= No zinc (control) M_1=No mulch (control)

F_2=50 ppm zinc M_2=White polythene mulch

F_3=100 ppm zinc M_3=Black Polythene mulch

F_4=150 ppm zinc

Interaction effect of zinc and mulch showed significant variation in terms of diameter of head under the present trial. The maximum (13.06cm) diameter of head was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment combination of F_1M_1 (zinc 0 ppm + no mulch) gave the minimum (10.59cm) diameter of head (Table 7)

4.16 Gross yield per plant (g/plant):

A statistically significant variation was recorded in terms of gross yield per plant due to the different level of zinc (Appendix XXVIII). Treatment F_3 gave the maximum (1292.49g) gross yield per plant which was statistically similar (1270.20g) with F_4 treatment, and the minimum was from (1147.29g) F_1 treatment (Table 8).

Gross yield per plant showed a significant variation was recorded for different mulching. The maximum (1363.28 g) gross yield per plant was recorded in from black polythene mulch (M_3) which was closely followed (1247.28 g) by M_2 (white polythene mulch) and the minimum (1093.15 g) was from control i.e. no mulch. From the results it was found that mulching increase the gross yield per plant and black polythene mulch was better than the white polythene mulch (Table 8). Carvalho *et al*. (2011) shows the same results.

Interaction effect of zinc and mulch showed significant variation in terms of gross yield per plant under the present trial. The maximum (1424.87g) gross yield per plant was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (zinc 0 ppm + no mulch) performed the minimum (942.67 g) gross yield per plant (Table 9).

4.17 Gross yield per plot (g/plot):

A statistically significant variation was recorded in terms of gross yield per plot due to the different level of zinc (Appendix XXIX). Treatment F_3 gave the maximum (15509.87 g) gross yield per plot which was statistically similar (15242.40 g) with F_4 treatment, and the minimum was from (13767.47 g) F_1 treatment (Table 8).

Gross yield per plot showed a significant variation was recorded for different mulching. The maximum (16359.40 g) gross yield per plot was recorded in from black polythene mulch (M_3) which was closely followed (14967.40 g) by M_2 (white polythene mulch) and the minimum (13117.8 g) was from control i.e. no mulch. From the results it was found that mulching increase the gross yield per plot and black polythene mulch was better than the white polythene mulch (Table 8). Akand (2003) reported that mulching increase the total plot yield in carrot.

Interaction effect of zinc and mulch showed significant variation in terms of gross yield per plot under the present trial. The maximum (17098.40 g) gross yield per plot was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (zinc 0 ppm + no mulch) performed the minimum (11312.00 g) gross yield per plot (Table 9).

4.18 Gross yield (t/ha):

A statistically significant variation was recorded in terms of gross yield per hectare due to the different level of zinc (Appendix XXX). Treatment F_3 gave the maximum (64.62ton/ha) gross yield per hectare which was statistically similar (63.51ton/ha) with F_4 treatment, and the minimum was from (57.36 ton/ha) F_1 treatment (Table 8).

Gross yield per hectare showed a significant variation was recorded for different mulching. The maximum (68.16 ton/ha) gross yield per hectare was recorded in from black polythene mulch (M_3) which was closely followed (62.36 ton/ha) by M_2 (white polythene mulch) and the minimum (54.66 ton/ha) was from control i.e. no mulch. From the results it was found that mulching increase the gross yield per hectare and black polythene mulch was better than the white polythene mulch (Table 8).

Interaction effect of zinc and mulch showed significant variation in terms of gross yield per hectare under the present trial. The maximum (71.24ton/ha) gross yield per hectare was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (zinc 0 ppm + no mulch) performed the minimum (47.13ton/ha) gross yield per hectare (Table 9).

4.19 Marketable yield per plot (g/plot):

A statistically significant variation was recorded in terms of marketable yield per plot due to the different level of zinc (Appendix XXXI). Treatment F_3 gave the maximum (10873.07 g) marketable yield per plot which was statistically similar (10762.40 g) with F_4 treatment, and the minimum was from (9532.27 g) F_1 treatment (Table 8).

Marketable yield per plot showed a significant variation was recorded for different mulching. The maximum (11513.80 g) marketable yield per plot was recorded in from black polythene mulch (M_3) which was closely followed (10569.20 g) by M_2 (white polythene mulch) and the minimum (9094.40 g) was from control i.e. no mulch. From the results it was found that mulching increase the marketable yield per plot and black polythene mulch was better than the white polythene mulch (Table 8).

Interaction effect of zinc and mulch showed significant variation in terms of marketable yield per plot under the present trial. The maximum (11949.60g) marketable yield per plot was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (Zinc 0 ppm + no mulch) performed the minimum (7529.60 g) marketable yield per plot (Table 9).

4.20 Marketable yield per ha (ton/ha):

A statistically significant variation was recorded in terms of marketable yield per hectare due to the different level of zinc (Appendix XXXII). Treatment F_3 gave the maximum (45.30 ton/ha) gross yield per hectare which was statistically similar (44.84 ton/ha) with F_4 treatment, and the minimum was from (39.72 ton/ha) F_1 treatment (Fig 12). Marketable yield per hectare showed a significant variation was recorded for different mulching. The maximum (47.97 ton/ha) marketable yield per hectare was recorded in from black polythene mulch (M_3)

which was closely followed (44.04 ton/ha) by M_2 (white polythene mulch) and the minimum (37.89 ton/ha) was from control i.e. no mulch. From the results it was polythene mulch was better than the white polythene mulch (Fig 13). Widjajanto *et al*. (2003) reported the similar findings from their experiment in earlier.

Interaction effect of zinc and mulch showed significant variation in terms of marketable yield per hectare under the present trial. The maximum (49.79ton/ha) marketable yield per hectare was recorded from the combined effect of F_3M_3 (zinc 100 ppm and black polythene mulch), while the treatment F_1M_1 (Zinc 0 ppm + no mulch) performed the minimum (31.37 ton/ha) marketable yield per hectare (Table 9).

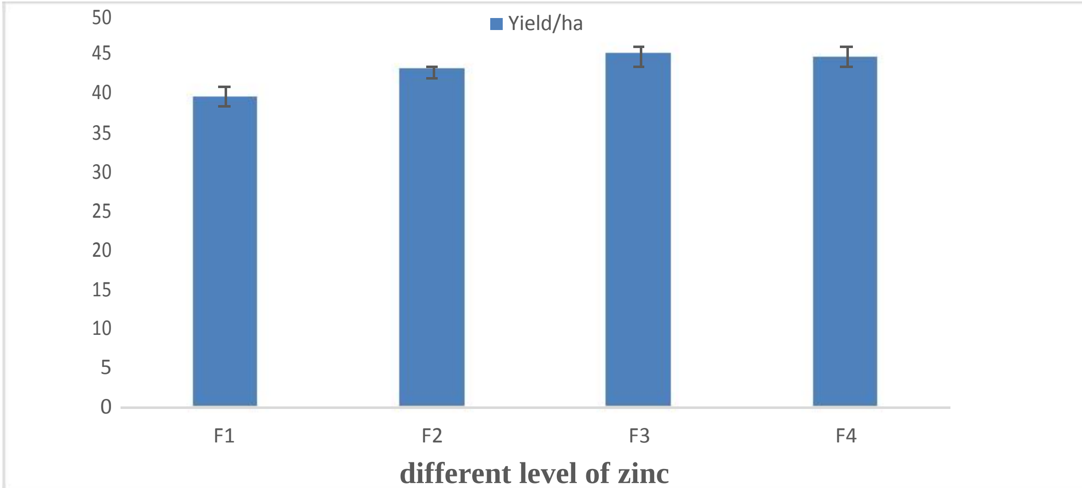


Fig 12: Effect of different level of zinc on marketable yield of red cabbage (LSD at 5% level)

F_1= No Zinc (Control), F_2=50 ppm Zinc, F_3=100 ppm Zinc, F_4=150 ppm Zinc

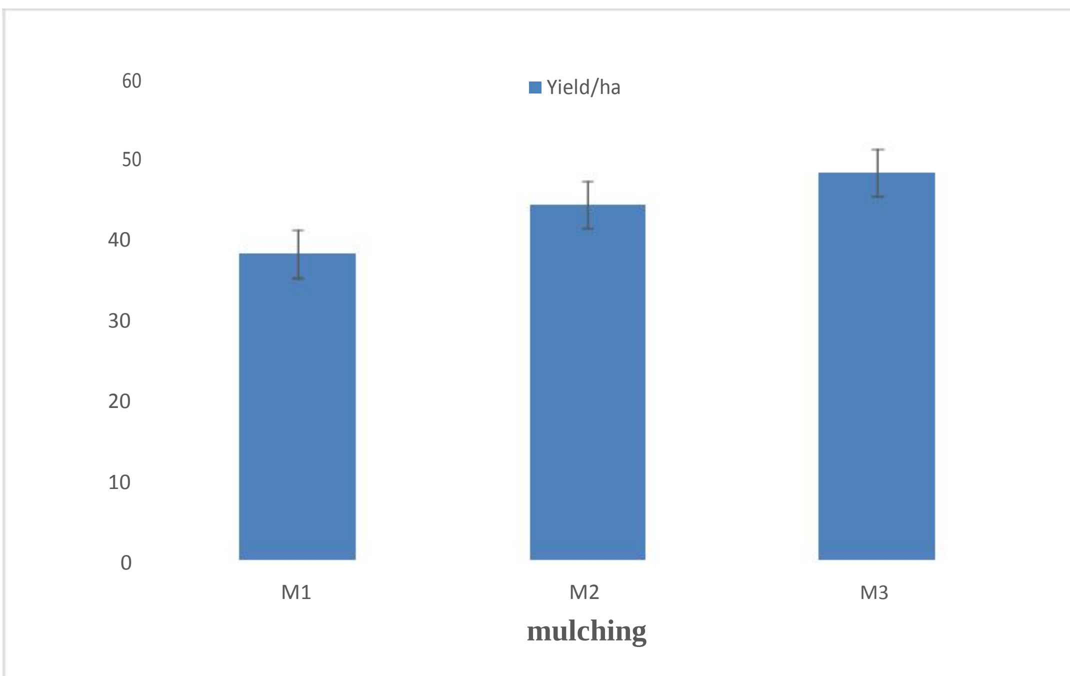


Fig 13: Effect of mulch materials on marketable yield of red cabbage (LSD at 5% level)

M_1=No mulch (Control), M_2=White polythene mulch, M_3=Black Polythene

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted in the Horticultural farm of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to January 2018.The experiment was conducted on Growth and Yield of Red Cabbage Influenced by Different Level of Zinc under Efficient Water Management Practice. The experiment was considered as two factors. Factor A: Zinc (4 levels): F_1 (0 ppm), F_2 (50 ppm) and F_3 (100 ppm), F_4 (150 ppm); Factor B: Mulches (3 levels) M_1 (No mulching/control), M_2 (White polythene mulch) and M_3 (Black polythene mulch). There were 12 (4 x 3) treatment combinations.

The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Data were collected on different parameters like plant height, leaf length, leaf breadth, no. of unfolded leaves, length of stem, thickness of head, head diameter, fresh wt. of head, root length, dry matter content, spread of plant, no. of leaves, total wt. of plant, fresh wt. of unfolded leaves, stem diameter, gross yield per plant, gross yield per plot, gross yield per ha, marketable yield per plot, marketable yield per ha.

Results revealed that different parameters were significantly influence by different levels of zinc. It was found that the highest plant height (22.70, 39.26, 39.38cm at 30, 45 and 60 DAT respectively), the maximum leaf length (18.64, 30.58, 33.98 cm at 30, 45 and 60 DAT respectively), the maximum no. of leaves (10.23, 13.32, 17.51 at 30, 45 and 60 DAT respectively), the maximum spread of plant (33.26, 54.46, 55.24 cm at 30, 45 and 60 DAT respectively), the maximum leaf breadth (10.62, 21.17, 24.42 cm at 30, 45 and 60 DAT respectively), were recorded from F_3 treatment. Again the maximum no. of unfolded leaves (8.84), the maximum stem length (5.27 cm), the maximum thickness of head(13.41 cm), the maximum head diameter (12.34 cm), the maximum fresh wt. of head (906.08gm), the maximum root length (16.70 cm), the maximum dry matter content (10.14%), the maximum total wt. of plant (1346.68gm), the maximum fresh wt. of unfolded leaves (386.40gm), the maximum diameter of stem (2.77cm), the highest gross yield per plant (1292.49g), the highest gross yield per plot (15509.87g)), the highest gross yield per ha (64.62t/ha), the highest marketable yield per plot (10873.07g) the highest marketable yield per ha (45.30 t/ha) were also recorded from F_3 treatment. Results also indicated that the lowest plant height (20.31, 33.98, 38.08cm at 30, 45 and 60 DAT respectively), the minimum leaf length (16.75, 28.78, 32.57 cm at 30, 45 and 60 DAT respectively), the minimum no. of leaves (8.73, 12.35, 16.64 at 30, 45 and 60 DAT respectively), the minimum spread of plant (29.33, 50.17, 52.44 cm at 30, 45 and 60 DAT respectively), the minimum leaf breadth (9.13, 18.84, 22.84 cm at 30, 45 and 60 DAT respectively), were recorded from F_1 treatment. Again the minimum no. of unfolded leaves (8.40), the minimum stem length (4.80 cm), the minimum thickness of head(12.69 cm), the minimum head diameter (11.62 cm), the minimum fresh wt. of head (794.35g), the minimum root length (15.77 cm), the minimum dry matter content (9.17%), the minimum total wt. of plant (1231.88gm), the minimum fresh wt. of unfolded leaves (352.93gm), the minimum diameter of stem (2.66cm), the lowest gross yield per plant (1147.29g), the lowest gross yield per plot (13767.47g), the lowest gross yield per ha (57.36t/ha), the lowest marketable yield per plot (9532.27g) the lowest marketable yield per ha (39.72 t/ha) were also recorded from F_1 treatment.

Different mulches applied in the red cabbage field had significant effect on different parameters. Results exposed that the highest plant height (24.16, 37.69, 40.00cm at 30, 45 and 60 DAT respectively), the maximum leaf length (19.45, 31.17, 35.10cm at 30, 45 and 60 DAT respectively), the maximum no. of leaves (11.11, 13.93, 18.01 at 30, 45 and 60 DAT respectively), the maximum spread of plant (35.13, 55.91, 56.48 cm at 30, 45 and 60 DAT respectively), the maximum leaf breadth (11.26, 22.10, 25.15 cm at 30, 45 and 60 DAT respectively), were recorded from M_3 treatment. Again the maximum no. of unfolded leaves (9.16), the maximum stem length (5.51 cm), the maximum thickness of head(13.83 cm), the maximum head diameter (12.72 cm), the maximum fresh wt. of head (959.48gm), the maximum root length (17.29 cm), the maximum dry matter content (10.45%), the maximum total wt. of plant (1408.10gm), the maximum fresh wt. of unfolded leaves (403.80gm), the maximum diameter of stem (2.86cm), the highest gross yield per plant (1363.28g), the highest gross yield per plot (16359.40g)), the highest gross yield per ha (68.16t/ha), the highest marketable yield per plot (11513.80g) the highest marketable yield per ha (47.97 t/ha) were also recorded from M_3 treatment.

Results also indicated that the lowest plant height (19.50, 32.69, 37.25cm at 30, 45 and 60 DAT respectively), the minimum leaf length (15.65, 27.95, 31.71 cm at 30, 45 and 60 DAT respectively), the minimum no. of leaves (7.92, 11.76, 16.17 at 30, 45 and 60 DAT respectively), the minimum spread of plant (27.95, 48.43, 51.16 cm at 30, 45 and 60 DAT respectively), the minimum leaf breadth (8.43, 17.86, 22.11 cm at 30, 45 and 60 DAT respectively), were recorded from M_1 treatment. Again the minimum no. of unfolded leaves (8.08), the minimum stem length (4.49 cm), the minimum thickness of head(12.38 cm), the minimum head diameter (11.19cm), the minimum fresh wt. of head (g), the minimum root length (15.24 cm), the minimum dry matter content (8.85%), the minimum total wt. of plant (1165.00gm), the minimum fresh wt. of unfolded leaves (335.28gm), the minimum diameter of stem (2.58cm), the lowest gross yield per plant (1093.15g), the lowest gross yield per plot (13117.80g), the lowest gross yield per ha (54.66t/ha), the lowest marketable yield per plot (9094.40g) the lowest marketable yield per ha (37.89 t/ha) were also recorded from M_1 treatment.

In terms of combined effect of different level of zinc and mulches the studied parameters were significantly influenced. Results demonstrated that the highest plant height (25.27, 38.47, 41.47cm at 30, 45 and 60 DAT respectively), the maximum leaf length (20.33, 32.67, 36.20 cm at 30, 45 and 60 DAT respectively), the maximum no. of leaves (11.67, 14.40, 18.53 at 30, 45 and 60 DAT respectively), the maximum spread of plant (36.40, 58.53, 57.60 cm at 30, 45 and 60 DAT respectively), the maximum leaf breadth (11.93, 23.46, 26.60 cm at 30, 45 and 60 DAT respectively), were recorded from F_3M_3 treatment. Again the maximum no. of unfolded leaves (9.46), the maximum stem length

(5.73 cm), the maximum thickness of head(14.19 cm), the maximum head diameter (13.06 cm), the maximum fresh wt. of head (995.80gm), the maximum root length (17.84 cm), the maximum dry matter content (11.79%), the maximum total wt. of plant (1447.06gm), the maximum fresh wt. of unfolded leaves (429.06gm), the maximum diameter of stem (2.91cm), the highest gross yield per plant (1424.87g), the highest gross yield per plot (17098.40g)), the highest gross yield per ha (71.24/ha), the highest marketable yield per plot (11949.60g) the highest marketable yield per ha (49.79 t/ha) were also recorded from F_3M_3 treatment.

Similarly, the lowest plant height (17.20, 30.33, 36.73cm at 30, 45 and 60 DAT respectively), the minimum leaf length (14.00, 26.20, 31.13 cm at 30, 45 and 60 DAT respectively), the minimum no. of leaves (6.60, 10.96, 15.53 at 30, 45 and 60 DAT respectively), the minimum spread of plant (22.93, 44.53, 48.33 cm at 30, 45 and 60 DAT respectively), the minimum leaf breadth (6.93, 15.53, 21.46 cm at 30, 45 and 60 DAT respectively), were recorded from F_1M_1 treatment. Again the minimum no. of unfolded leaves (7.86), the minimum stem length (4.13 cm), the minimum thickness of head(11.82 cm), the minimum head diameter (10.59 cm), the minimum fresh wt. of head (627.46g), the minimum root length (14.43 cm), the minimum dry matter content (8.61%), the minimum total wt. of plant (1052.60gm), the minimum fresh wt. of unfolded leaves (315.20gm), the minimum diameter of stem (2.49cm), the lowest gross yield per plant (942.67g), the lowest gross yield per plot (11312..00g), the lowest gross yield per ha (47.13t/ha), the lowest marketable yield per plot (7529.60g) the lowest marketable yield per ha (31.37 t/ha) were also recorded from F_1M_1 treatment.

Conclusion and suggestion

From the above discussion, it may be concluded that

- In the experiment zinc dose at medium level (zinc 100 ppm) gave better performance for growth and yield.
- Black polythene mulch was more effective than white polythene mulch.
- During the investigation, the treatment combination of F_3M_3 (100 ppm zinc with black polythene) was the best due to highest gross yield, and marketable yield
- Considering the situation of the present experiment, further studies might be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.

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APPENDICES

Appendix I. Physical characteristics and chemical composition of the soil of the experimental plot

Soil characteristics	Analytical results
Agrological Zone	Madhupur Tract
pH	6.00-6.63
Organic matter	0.84
Total N (%)	0.46
Available phosphorus	21 ppm
Exchangeable K	0.41 meq / 100g soil

Source: Soil resource and development institute (SRDI), Dhaka

Appendix II. Monthly recorded the average air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from October 2017 to March 2018.

Month	Air temperature		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
October, 2017	31.6	23.8	78	172.3	5.2
November, 2017	29.6	19.2	77	34.4	5.7
December, 2017	26.4	14.1	69	12.8	5.5
January, 2018	25.4	12.7	68	7.7	5.6
February, 2018	28.1	15.5	68	28.9	5.5
March, 2018	32.5	20.4	64	65.8	5.2

Source: Bangladesh Meteorological Department (Climate & Weather Division) Agargoan, Dhaka – 1212.

Appendix III. Analysis of variance on plant height at 30 DAT

Source of variance	SS	df	MS	F-value	Significance level
Zinc	29.07	3	9.69	2.06	0.12
Mulch	131.24	2	65.62	44.59	0.00
Zinc × Mulch	165.94	11	15.08	26.13	0.00

Appendix IV. Analysis of variance on plant height at 45 DAT

Source of variance	SS	df	MS	F-value	Significance level
Zinc	25.10	3	8.37	1.49	0.23
Mulch	150.11	2	75.05	45.923	0.00
Zinc × Mulch	183.91	11	16.72	19.94	0.00

Appendix V. Analysis of variance on plant height at 60 DAT

Source of variance	SS	df	MS	F-value	Significance level
Zinc	7.89	3	2.63	1.32	0.28
Mulch	55.41	2	27.70	56.66	0.00
Zinc × Mulch	65.02	11	5.91	21.73	0.00

Appendix VI. Analysis of variance on no. of leaves at 30 DAT

Source of variance	SS	df	MS	F-value	Significance level
Zinc	10.77	3	3.59	1.74	0.17
Mulch	58.39	2	29.19	53.27	0.00
Zinc × Mulch	70.88	11	6.44	27.68	0.00

Appendix VII. Analysis of variance on no. of leaves at 45 DAT

Source of variance	SS	df	MS	F-value	Significance level
Zinc	4.70	3	1.56	1.58	0.21
Mulch	28.18	2	14.09	56.35	0.00
Zinc × Mulch	33.48	11	3.04	24.67	0.00

Appendix VIII. Analysis of variance on no. of leaves at 60 DAT

Source of variance	SS	df	MS	F-value	Significance level
Zinc	3.76	3	1.25	1.46	0.24
Mulch	20.35	2	10.17	30.78	0.00
Zinc × Mulch	24.45	11	2.22	7.84	0.00

Appendix IX. Analysis of variance on leaf length at 30 DAT

Source of variance	SS	df	MS	F-value	Significance level
Zinc	16.77	3	5.59	1.83	0.16
Mulch	88.38	2	44.19	56.13	0.00
Zinc × Mulch	108.49	11	9.86	40.34	0.00

Appendix X. Analysis of variance on leaf length at 45 DAT

Source of variance	SS	df	MS	F-value	Significance level
Zinc	16.16	3	5.38	1.87	0.15
Mulch	63.93	2	31.96	23.83	0.00
Zinc × Mulch	85.06	11	7.73	8.02	0.00

Appendix XI. Analysis of variance on leaf length at 60 DAT

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	9.53	3	3.18	1.33	0.28
Mulch	70.88	2	35.44	79.28	0.00
Zinc × Mulch	81.56	11	7.41	43.61	0.00

Appendix XII. Analysis of variance on leaf breadth at 30 DAT

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	10.68	3	3.56	2.07	0.12
Mulch	48.74	2	24.37	47.27	0.00
Zinc × Mulch	62.44	11	5.67	41.19	0.00

Appendix XIII. Analysis of variance on leaf breadth at 45 DAT

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	25.83	3	8.61	1.94	0.14
Mulch	108.29	2	54.14	30.11	0.00
Zinc × Mulch	142.88	11	12.99	12.60	0.00

Appendix XIV. Analysis of variance on leaf breadth at 60 DAT

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	12.48	3	4.16	1.65	0.19
Mulch	55.21	2	27.60	24.14	0.00
Zinc × Mulch	71.75	11	6.52	7.38	0.00

Appendix XV. Analysis of variance on Canopy at 30 DAT

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	82.36	3	27.45	2.16	0.11
Mulch	314.41	2	157.20	29.65	0.00
Zinc × Mulch	437.12	11	39.74	18.26	0.00

Appendix XVI. Analysis of variance on Canopy at 45 DAT

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	86.23	3	28.74	1.94	0.14
Mulch	339.83	2	169.91	25.49	0.00
Zinc × Mulch	452.87	11	41.17	9.24	0.00

Appendix XVII. Analysis of variance on Canopy at 60 DAT

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	37.23	3	12.41	1.89	0.15
Mulch	171.81	2	85.90	37.72	0.00
Zinc × Mulch	218.93	11	19.90	17.04	0.00

Appendix XVIII. Analysis of variance on No. of unfolded leaves

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	1.03	3	0.34	1.27	0.30
Mulch	7.04	2	3.52	43.85	0.00
Zinc × Mulch	8.14	11	0.74	11.432	0.00

Appendix XIX. Analysis of variance on Fresh weight of unfolded leaves

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	5720.00	3	1906.67	1.78	0.17
Mulch	28240.41	2	14120.20	39.68	0.00
Zinc × Mulch	34865.81	11	3169.62	14.86	0.00

Appendix XX. Analysis of variance on Total plant weight

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	72304.86	3	24101.62	1.77	0.17
Mulch	357727.26	2	178863.63	39.24	0.00
Zinc × Mulch	453724.76	11	41247.70	18.18	0.00

Appendix XXI. Analysis of variance on Head weight (gm)

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	69241.53	3	23080.51	2.31	0.09
Mulch	247800.01	2	123900.00	28.99	0.00
Zinc × Mulch	338824.84	11	30802.26	14.78	0.00

Appendix XXII. Analysis of variance on Dry matter content

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	4.84	3	1.61	2.28	0.09
Mulch	15.97	2	7.98	23.06	0.00
Zinc × Mulch	24.33	11	2.21	17.29	0.00

Appendix XXIII. Analysis of variance on Stem length (cm)

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	1.20	3	0.40	1.43	0.25
Mulch	6.34	2	3.17	27.36	0.00
Zinc × Mulch	7.81	11	0.71	7.25	0.00

Appendix XXIV. Analysis of variance on Stem diameter

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	0.07	3	0.02	1.14	0.35
Mulch	0.48	2	0.24	33.92	0.00
Zinc × Mulch	0.56	11	0.05	7.63	0.00

Appendix XXV. Analysis of variance on Root length

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	4.00	3	1.34	1.16	0.34
Mulch	25.28	2	12.64	27.02	0.00
Zinc × Mulch	30.19	11	2.74	6.26	0.00

Appendix XXVI. Analysis of variance on Thickness

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	2.63	3	0.88	1.48	0.24
Mulch	12.69	2	6.34	23.51	0.00
Zinc × Mulch	15.58	11	1.42	5.65	0.00

Appendix XXVII. Analysis of variance on Head diameter

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	2.43	3	.81	1.47	0.24
Mulch	14.11	2	7.05	39.72	0.00
Zinc × Mulch	16.91	11	1.54	12.08	0.00

Appendix XXVIII. Analysis of variance on Gross yield per plant

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	110531.35	3	36843.78	2.24	0.10
Mulch	440740.41	2	220370.20	36.97	0.00
Zinc × Mulch	578212.71	11	52564.79	21.30	0.00

Appendix XXIX. Analysis of variance on Gross yield per plot

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	15916513.76	3	5305504.59	2.24	0.10
Mulch	63466618.88	2	31733309.44	36.97	0.00
Zinc × Mulch	83262629.60	11	7569329.96	21.30	0.00

Appendix XXX. Analysis of variance on Gross yield per ha

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	276.33	3	92.11	2.24	0.10
Mulch	1101.85	2	550.93	36.97	0.00
Zinc × Mulch	1445.53	11	131.41	21.30	0.00

Appendix XXXI. Analysis of variance on Marketable yield per plot

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	9970780.64	3	3323593.55	2.31	0.09
Mulch	35683202.24	2	17841601.12	28.99	0.00
Zinc × Mulch	48790776.80	11	4435525.16	14.78	0.00

Appendix XXXII. Analysis of variance on Marketable yield per ha

Source of variance	SS	Df	MS	F-value	Significance level
Zinc	173.10	3	57.70	2.31	0.09
Mulch	619.50	2	309.75	28.99	0.00
Zinc × Mulch	847.06	11	77.00	14.78	0.00