GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY GA_3 AND MULCHING

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CERTIFICATE

This is to certify that the thesis entitled " Growth and yield of cabbage as influenced by GA_3 and mulching" 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 MASTERS OF SCIENCE (M.S.) in HORTICULTURE, embodies the result of a piece of bonafide research work carried out by DILARA ISLAM NILA, Registration No. 13-05420 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.

June, 2020

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Dedicated
to
My Beloved Parents

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The Author

GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY GA_3 AND MULCHING

ABSTRACT

To study growth and yield of cabbage as influenced by GA_3 and mulching a field study was carried out at the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2018 to March 2019. Cabbage seeds of Atlas 70 were used as planting materials. The experiment consisted of two factors: Factor A: three mulching materials *viz*. M_0 = Control, M_1 = Polythene mulch and M_2 = Straw mulch and Factor B: Four levels GA_3 application *viz*. G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3 and G_3 = 120 ppm GA_3. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Results revealed that the mulching treatment M_1 (polythene mulch) showed promising results on growth and yield parameters and it was the treatment compared to others which showed the highest marketable cabbage yield (43.03 t ha^{-1}) whereas the lowest (40.26 t ha^{-1}) was from M_0 (control condition). Among the GA_3 treatment, G_2 (100 ppm GA_3) gave the best performance for most of the studied parameters and showed highest marketable yield ha^{-1} (46.23 t ha^{-1}) whereas the lowest (35.82 t ha^{-1}) was from control treatment G_0 (0 ppm GA_3). Different treatment combination of mulching and GA_3 also showed significant influence on different growth and yield parameters of cabbage. The highest gross yield (55.76 t ha^{-1}) and marketable yield (47.43 t ha^{-1}) were recorded from the treatment combination of M_1G_2 whereas the lowest (40.49 and 34.63 t ha^{-1}, respectively) were found from M_0G_0. Regarding economic analysis, the highest Benefit cost ratio (BCR) (3.37) was also recorded from M_1G_2 whereas the lowest BCR (2.38) was obtained from the treatment combination of M_0G_0. From growth, yield and also economic point of view, it is apparent that the combination of M_1G_2.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea* var. capitata L.) locally known as 'badhacopy' is an important leafy vegetables crop commonly suited in low land culture and normally grown in Rabi season (15 October to 16 March) throughout Bangladesh. It is a member of the family Brassicaceae (or Cruciferae). It is a herbaceous, biennial, dicotyledonous flowering plant distinguished by a short stem upon which is crowded mass of loose leaves , usually green but in some varieties red or purplish, which while immature form a characteristic compact, globular cluster structure is known as cabbage head. The head is used as salad, boiled vegetable, cooked in curries, used in pickling as well as dehydrated vegetable. Cabbage head is an excellent source of many nutrients especially vitamin C, vit. B6, vit. K, folate, biotin, calcium, magnesium, potassium and manganese (Singh *et al.*, 2004, Pennington and Fish, 2010 and Moniruzzaman *et al*, 2019). It also contains significant amounts of glutamine, an amino acid that has anti-ulcer properties. Cabbage is a source of indole-3-carbinol, a chemical which boosts DNA repair in cells and appears to block the growth of cancer cells. The taste in cabbage is due to the "Sinigrin glucoside" (Singh *et al.*, 2004 and Moniruzzaman *et al*, 2019).

Among the various factors to influence production of cabbage, soil moisture and nutrient availability to plant are most important criteria to increase the production. Mulching is an important factor for successful crop yield. It absorbs the heat from the solar radiation, increases the soil temperature and helps to increase the crop production especially in the winter season. Also, it reduces the cost through reducing the weed infestation in the field and moisture conservation (Chakraborty *et al.*, 2008). Cabbage occupied an area of 46 thousand acres of land during 2017 growing season with a total production of 312 thousand metric tons in Bangladesh (BBS, 2017). Thus the average yield was 16.85 t/ha. This is considered as low yield compared to that of other countries of the world, viz., South Korea (61.17 t/ha), Germany (54.81 t/ha.), Japan (40.32 t/ha) and India (19.10t/ha). Such a poor yield attributed to a greater extent on the method of production technology followed by the farmers.

Growth and yield of the vegetable crop is remarkably influenced by nutrients management along with mulching to control weed and conserve soil moisture (Döring *et al*., 2005; Murungu *et al*., 2011; Ramakrishna *et al*., 2006). Also, it improves soil quality, productivity and quality of product for consumption. Mulching helps to control weeds effectively by reducing physiological functions of weed like germination, root, shoot and stem growth etc., ultimately reduce the production cost (Duppong *et al*., 2004). On the other hand, different types of mulch like natural or artificial mulch can have the influence on crop production. It is necessary to identify which will be beneficial for higher production of cabbage. Because, natural mulch helps to add organic matter to soil and artificial mulch increase the temperature of soil, conserve soil moisture and reduce the weed competition (Murungu *et al*., 2011).

There is a necessity of boosting up vegetable production to increase the per capita per day intake of vegetables in Bangladesh. Application of plant growth regulator is one of the best means for the increased vegetable production. Nowa- days, plant growth regulators have been tried to improve growth and ultimately yield. Growth regulators are organic compounds other than nutrients; small amounts of which are capable of modifying growth. Among the growth regulators, auxin causes enlargement of plant cell and gibberellins stimulates cell division, cell enlargement or both (Nickell, 1982). Gibberellic acid (GA_3) exhibited beneficial effect in several crops (Thapa *et al*., 2013; Mello *et al*, 2013; and Roy and Nasiruddin, 2011). Due to diversified use of productive land, it is necessary to increase food production and growth regulators may be a contributor in achieving the desired goal. Cabbage was found to show a quick growth, increase number of loose leaves /plant and higher yield when treated with plant growth regulator especially GA_3 (Dhengle *et al*., 2008; Yadav *et al*., 2000; Kumar *et al*., 1996). Cabbage was found to show a quick growth when treated with plant growth regulators (Islam *et al*., 1993). Application of GA_3 stimulates morphological characters like plant height, number of loose leaves , head diameter, thickness of head as well as the weight of head (Mazed *et al*., 2015).

In recent years vegetable consumption has increased. However, the productivity of cabbage per unit area is quite low in Bangladesh as compared to the developed countries of the world. Considering this, it is very much important to sustain the production of cabbage. Growth regulators like GA_3 and mulch are important factors which can have the influence on cabbage production. Considering the above factors, the present study was undertaken to find out the growth and yield of cabbage as influenced by GA_3 and mulching effect of different mulching treatment and concentrations of GA_3 for better vegetative growth, maximum yield and economic return of cabbage. In view of the above facts, the present research work will undertaken with the following objectives

1. To find out the optimum level of GA_3 for growth and yield of cabbage
2. To investigate suitable mulch materials for growth and yield of cabbage
3. To investigate the suitable combination of GA_3 and mulch materials for ensuring the higher growth and yield of cabbage

CHAPTER II

REVIEW OF LITERATURE

Cabbage is one of the leading vegetables of rabi season in our country. Management practices have considerable effects on the growth and development of any crop particularly vegetable crops. Among these, mulching practice and growth regulators are modern concept as a management practices. Numerous studies have been performed evaluating the influence of mulching and GA_3 as growth regulators on the performance of cabbage. Among the above factors some of the recent past information on mulching and GA_3 on cabbage have been reviewed under the following headings:

2.1 Effect of mulching

Mulches are used for various reasons in agriculture but water conservation and erosion control are the most important objectives particularly in arid and semi-arid regions. Other reasons for use of mulching include soil temperature modification, weed control, soil conservation and after decomposition of organic mulch add plant nutrients, improvement in soil structure, increase crop quality and yield. Mulching reduces the deterioration of soil by way of preventing the runoff and soil loss, minimizes the weed infestation and reduces water evaporation.

2.1.1 Organic mulches

Organic mulches are derived from plant and animal materials such as straw, hay, peanut hulls, leaf mold, compost, sawdust, wood chips, shavings and animal manures. To achieve optimum advantage from the organic mulch, the mulch should be applied immediately after germination of crop or transplanting of vegetable seedling @ 5 t ha^{-1}. Organic mulch are efficient in reduction of nitrates leaching, improve soil physical properties, prevent erosion, supply organic matter, regulate temperature and water retention, improve nitrogen balance, take part in nutrient cycle as well as increase the biological activity (Hooks and Johnson, 2003; Muhammad *et al*,, 2009; Sarolia and Bhardwaj, 2012). Natural materials can not be easily spread on growing crops and require considerable human labour (Bhardwaj, 2011).

2.1.3 Inorganic mulches

Inorganic mulch includes plastic mulch and accounts for the greatest volume of mulch used in commercial crop production. The plastic materials used as mulch are poly vinyl chloride or polyethylene films. Owing to its greater permeability to long wave radiation it can increase temperature around the plants during night in winter. Hence, polyethylene film mulch is preferred as mulching material for production of horticultural crops (Bhardwaj *et al.,* 2011). A wide range of plastic films based on different types of polymers have all been evaluated for mulching at various periods in the 1960s. LDPE, HDPE and flexible PVC have all been used and although there were some technical performance differences between them, they were of minor nature. Today the vast majority of plastic mulch is based on LLDPE because it is more economic in use. Now a day's application of black plastic mulch film is becoming popular and very good results have been achieved particularly in arid and semi-arid regions (Bhardwaj *et al.,* 2011). Black polyethylene mulches are used for weed control in a range of crops under the organic system of crop production. The use of black polypropylene woven mulch is usually restricted to perennial crops. Murugan and Gopinath (2001) verified the efficacy of organic mulches (dried leaves, coconut fronds and coir pith) and inorganic mulches (black polyethylene 25, 50 and 100) on growth attributes of Saundarya cv of crossandra at Bangalore. Likewise, different cultivars of carnation in poly house significantly improved plant height, number of branches, flower size and yield with the application of black polyethylene mulch (Arora *et al.,* 2002).

2.1.4 Effect of mulching on plants

Mulching provides a favourable environment for growth which results in more vigorous, healthier plants which may be more resistant to pest injury. Increase in soil temperature and moisture content stimulate root growth which leads to greater plant growth. Therefore, mulched plants usually grow and mature more uniformally than unmulched plants (Bhardwaj *et al.,* 2011; Sarolia and Bhardwaj 2012). Hassan *et al.* (1994) and Yamaguchi *et al.* (1996) revealed that combination of reflective film mulching and shading treatments increased plant height, length of primary and secondary branches of carnation seedlings.

Lourduraj *et al.* (1996) obtained highest plant height (81.5 cm) and number of laterals (8.6 per plant) in tomato with the application of black LLDPE mulch as compared to organic mulch and no mulch. Similar results were also reported by Kim *et al.* (2000) in *Crocosmia crocosmiiflora,* Hong *et al.* (2001) in lilies. Gao *et al.* (2001) the nutrient paper mulch advanced plant growth as compared to plastic mulch and no mulch in tomato.

Barman *et al.* (2005) recorded significant improvement in number of days taken for first floret opening, spike length and rachis length with the application of paddy straw mulch in gladiolus.

Chawla (2006) obtained maximum plant height (70.91 cm), plant spread (53.05 cm) and highest number of branches (18.54) at harvest in marigold cv. Double mix with application of black plastic mulch compared to other mulching treatment.

Promote early harvest: Warm season vegetables such as cucumbers, muskmelons, watermelons, eggplant, peppers, usually respond to mulching in terms of early maturity and higher yields. An early maturity is probably due to maintenance of favourable temperatures during growing season. Black mulch applied to the planting bed prior to planting will warm the soil and promote faster growth in early season, which generally leads to earlier harvest (Tarara, 2000 and Lamont, 2005).

Organic mulches induced earliness in flowering, less days to fruit set and harvest in tomato crop over control (Ravinderkumar and Shrivastava, 1998). Applications of polyethylene films as mulch have shortened growing season and enhanced earliness and yield in different vegetable crops (Goreta *et al.,* 2005; McCann *et al.,* 2007). Beneficial effect of polyethylene mulch on early harvest and higher yield was also found for watermelon (Romic *et al.*, 2003), zucchini (Walters, 2003), tomato and pepper (Hutton and Handley, 2007).

Mulch helps keep fruits clean from contacting the ground, reduces soil rot, fruit cracking and blossom end rot in many cases. Fruits tend to be smoother with fewer scars. Properly installed plastic mulch helps keep soil from splashing onto the plants during rainfall, which can reduce grading time. The yield and chemical composition of tomatoes, cucumbers, muskmelons, eggplant, were found to be improved. The yield and keeping quality of early potatoes, cabbage and other vegetables may be improved by straw mulch. Application of straw mulch @ 6 t ha^{-1} increased yield of tomato and okra by 100 and 200 per cent, respectively over control (Gupta and Gupta, 1987).

Marketable fruit yield from mulched plot was significantly higher than those produced on bare soil. This difference can be attributed to moisture conservation, higher soil temperature, weed control, and increased mineral nutrient uptake in the mulched plot through improved root temperatures, as reported by Orozco *et al.* (1994). Gollifer (1993) reported that application of organic mulch @ 40 t ha^{-1} produced 2.5 t ha^{-1} of chilli dry fruits.

Hassan *et al.* (1994) reported that organic mulch gave higher fruit yield of bell pepper than control. The yield (27.9 per cent) and starch content (18.18 per cent) of potato was increased with paddy straw mulch over unmulched (Dixit and Majumdar, 1995). Aref *et al.* (1996) reported that application of hairy vetch mulch recorded significantly higher yield of tomato (32 per cent) than bare soil.

Lourduraj *et al.* (1996) obtained highest number of fruits (42), average fruit weight (31.8 g) and yield (12.73 t ha^{-1}) in tomato cv. CO-3 with application of black LLDPE mulch compared to organic and no mulch. Mulching increased crop weight by 16 per cent compared with non mulched plots in leek.

Thakur *et al.* (2000) reported that the use of different mulches on the performance of *Capsicum annuum* L. under water deficit of 75 per cent, the lantana mulch gave the highest fruit yield of 7.34 t ha^{-1} over unmulched plots (3.69 t ha^{-1}). They also reported that yield levels increased by 198 per cent in plastic mulch, 164 percent in lantana leaves and 141 percent in grass mulched plants over unmulched plants of capsicum. These findings are in agreement with Gangwar *et al.* (2000) who reported that paddy straw mulch on mulberry showed maximum leaf yield (46%) compared to sorghum (32.4%) and blackgram mulching (23.08%) over control. Murugan and Gopinath (2001) obtained maximum duration of flowering and advanced flowering in crossandra cv. Saundrya by using black polyethylene mulch as compared to organic mulches.

Gao *et al.* (2001) reported that the nutrient paper mulching promoted flower bud differentiation enhanced yield and improved fruit quality in tomato as compared to the plastic mulch or no mulching.

Nagalakshmi *et al.* (2002) obtained the maximum number of fruits per plant (97.67), length of fresh fruit (6.93 cm), circumference of fruit (3.57 cm) and yield of chilli (8.60 t ha^{-1}) with the application of black LLDPE mulch compared to organic mulch and no mulch.

Gandhi and Bains (2006) reported that the crop under straw mulch produced higher number of branches (8.7), fruit weight (28.08 g) and total yield (49.63 t ha^{-1}) as compared to no mulch (8.1, 27.86 g and 47.85 t ha^{-1} respectively) in tomato.

Chawla (2006) obtained highest number of flowers per plant (53.45), average flower weight (47.21 g/10 flowers), maximum flower diameter (5.47 cm) and highest flower yield (11.66 t ha^{-1}) in marigold cv. Double mix with application of black LLDPE mulch compared to white LLDPE mulch, organic mulch and no mulch. Shashidhar *et al.* (2009) reported that the total leaf yield of mulberry was found maximum in paddy straw mulched plots (15.20 t ha^{-1}) as compared to control plots (11.78 t ha^{-1}).

By providing a physical barrier, mulching reduces the germination and nourishment of many weeds. The mulching operation favours in the reduction of weed seed germination, weeds growth and keeps the weed under control (Vander Zaag *et al.,* 1986).

Covering or mulching the soil surface can prevent weed seed germination or physically suppress seedling emergence. Loose materials such as straw, bark and composted municipal green waste can provide effective weed control (Merwin *et al.,* 1995).

Saw dust is a soil improver and weed suppressor as it conserves soil moisture, decreases run-off, increases infiltration and percolation, decreases evaporation and weed growth can be substantial under clear mulch (Waterer, 2000).

White or clear mulch and green covering had little effect on weeds, whereas brown, black, blue or white on black (double color) films prevented emerging weeds (Bond and Grundy, 2001). Ossom *et al.* (2001) also observed significant differences in weed control between mulched and unmulched plots of eggplant.

Kalisz and Cebuia (2001) carried out an experiment in Poland to conclude the effect of soil mulched with polythene film and plant covered with non-woven polypropylene and perforated polythene film on the growth and yield turnip during the period 1997-98. Plants coverings were given directly after planting the transplants. Soil mulching was spread 1-2 days before the beginning of the field experiment. They observed that plant height, root diameter and the number of loose leaves and their area build-up by the plastic covers considerably improved plant growth. Among the treatments, non-woven polypropylene recorded the highest (90.38 and 60.74 t/ha in 1997 and 1998, respectively) and the control treatment recorded the lowest yields (28.80 and 26.37 t/ha).

Efficiency of different mulches is again a point to be considered in an experiment while Hossain (1999) working with different mulches on the growth and yield of 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 in the Horticulture Farm, BangladeshAgricultural University, Mymensingh and reported 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 that as an alternative to irrigation, water hyacinth and straw can be adopted as feasible mulches to increase the yield by conserving the residual soil moisture.

Rahman (1995) reported similar results for black polythene mulching while conducting an experiment in Bangladesh Agricultural Research Institute, Ga/.ipur, Bangladesh, adding that paddy husk had been found to be more effective in increasing the growth and yield of cabbage which straw mulch had adverse effects.

Hembry el al. (1994) conducted an experiment in Horticulture Research International, Warwick, UK to evaluate a range of ground cover mulches including black paper, black polythene and straw for their effect on weed control. They reported excellent weed control and maximum yield with all mulches except straw.

Stolze et al. (2000) reported a comprehensive overview of European research focused on the relationship between organic production practices and environmental quality. The study was designed to provide a qualitative assessment of the impact of organic farming on the environment and resource use compared with that of conventional farming practices. Besides addressing water quality issues such as nitrate leaching and runoff from compost piles, this review also addresses flora and fauna diversity, energy use, animal health and welfare, and food quality of organically produced foods. Rated on a scale from "much better" to "much worse" (overall) organic farming was rated "the same as" conventional farming systems in about 40 percent of the categories, "better" in 40 percent, and "much better" in 20 percent.

Conacher and Conacher (1998) begin with a discussion of environmental benefits commonly attributed to organic farming systems, including improvements in soil structure and porosity, water infiltration and water-holding capacity, nutrient cycling and nutrient retention, and buffering against pest and disease infestations. In reference to Australia the authors stress the ability of organic farming practices to build up soil organic matter reserves to restore hydrological balances and enhance soil structure in saline soils.

Drinkwater et al. (1998) reported that Nitrogen and carbon losses from organic and conventionally managed fields were analyzed over 15 years. Immobilization of nitrogen by soil organisms and soil organic matter caused nitrogen to accumulate in organically managed fields. Conventional fields had less nitrogen immobilization and more nitrate leaching than the organic plots. Nitrate-leaching was 50% more in the conventionally managed fields compared to the organically managed fields. In addition, organic fields had higher water infiltration rates, higher water holding capacity, reduced soil erosion, and increased soil productivity.

Pang and Letey (2000) estimates the rates and amounts of nitrogen mineralized from organic materials are not consistent with nutrient needs of turnip and other crops grown under organic production methods. To meet nutrient demands of turnip, excessive amounts of manure must be applied. As this manure mineralizes, nitrate not taken up by the crop plants is susceptible to leaching. Turnip varieties have a narrow time period during which they require high nitrogen availability to obtain optimum yields. Nitrogen mineralization occurs too gradually to meet these peak demands, resulting in sub-optimal yields. Mineralization that continues beyond the time of peak nitrogen uptake can release nitrate, which is then subject to leaching

Mikkelsen (2000) reported about nutrient management practices, processes used to manage land in organic farming, and potential problems that could arise in the certification of organic farms. The case study describes an organic vegetable farming operation that uses poultry manure as a source of organic matter and nutrients. Unfortunately, the manure additions have resulted in buildups of copper and zinc in the soil because these compounds were used as feed supplements for poultry. The concentrations of these heavy metals in the soil have limited the farmer's ability to grow ccrtain copper-sensitive crops and are causing him problems in trying to keep his organic certification.

Truggelmann et al. (2000) reported that the best yield and quality results for vegetable production in Philippine soils are obtained, when a combination of organic and inorganic fertilizers is applied. Organic fertilizers such as manure and compost are needed to improve the physical, biological and chemical properties of the soil while inorganic fertilizers such as urea, muriate of potash, and others supply sufficient amounts of readily available nutrients. Organic fertilizers supply the same essential plant nutrients as inorganic fertilizers. The major difference is in their availability and concentration. Inorganic fertilizers contain nutrients that are available immediately and highly concentrated. While organic fertilizers normally do not exceed values of 3% for nitrogen, phosphorous and potassium, those are much higher in inorganic fertilizers (46% N in urea, 60% KjO in muriate of potash, 46% P2O5 in DAP). If one wishes to grow crops only with organic fertilizers, it has to be considered that tons per hectare must be applied to supply typical crop nutrient needs.

Liu and Hu (2000) carried oul an experiment on growing turnip in an area of 2900 m above sea level in Gansu, China indicated that plastic mulching would promote the growth and yield of the turnip by improving soil temperature and moisture. Compared with the control (without mulching), the crop with mulching had earlier emergence by 6 days, a 2-fold faster average growth rates, a 1.65-fold larger maximum leaf area index, a 15 days longer closed canopy, a 20.8% higher yield and increased protein, fibre, Ca and P. Highest yield was attained than control.

Crusciol *et al*. (2005) reported that straw of covering plants kept on soil surface in no-tillage system is an important source of nutrients for subsequent tillage. This study investigated the decomposition and release of macronutrients from forage turnip residues. The experiment was set under field conditions during 1998 in Marechal Candido Rondon, Parana, Brazil. Forage turnip plants were desiccated and lodged 30 days after emergence. Straw persistence and nutrient release were evaluated at 0, 13, 35, and 53 days after management. Untill per-flowering stage, the crop turnip showed a high dry matter yield (2938 kg/ha) during winter, and accumulated 57.2, 15.3, 85.7 and 14.0 kg/ha of N, P, K, Ca, Mg and S, respectively. Forage turnip management at pre-flowering stage resulted a quick straw degradation and macronutrients release. Potassium and N were released in the highest amounts and in the shortest time to subsequent tillage. The fastest liberation of nutrients occurred between 10 and 20 days after plant management.

Albayrak et al. (2004) conducted an experiment to identify the effects of four row spacing (20,30,40, and 50cm) on root and leaf yield and some yield components of four forage turnips (.Brassica rapa [B. campestris]) (diploid cultivars Agressa, Slioganova, tetraploid cultivars Polybra Volenda) were evaluated under the Black Sea Coastal Area Conditions in the 2002 and 2003 growing seasons. The root yield, root dry matter yield, root crude protein yield, root diameter, root length, leaf yield, leaf dry matter yield, and leaf crude protein yield were determined. Row spacing significantly affected most of the yield components determiner in forage turnip cultivars. Root and leaf yields and their yield components increased along with increase of row spacing. The highest root and leaf dry matter yields were obtained from the 40 cm row spacing. The Volenda cultivar had the highest yield under the Black Sea Coastal Area Conditions.

Farjana and Islam (2019) conducted a study with the purpose of cabbage growth and yield with organic and inorganic fertilizers, and mulching. The experiment comprised of two different factors such as, factor-A; four different types of fertilizers viz. F0 (control, no fertilizer), F1 (vermicompost), F2 (inorganic fertilizer), and F3 (mixed of organic and inorganic fertilizer) and factor-B; types of mulches viz. M0 (control, no mulch), M1 (water hyacinth), M2 (rice straw), M3 (black polythene). This two factors experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. Findings: Significant variation was found among the treatments. Result showed F3M3 (combination organic and inorganic fertilizer with black polythene) had the highest growth (plant height, stem length, root length, number of roots etc.) and yield (105.93 t/ha) in cabbage. The yield was 63.92% higher from the combined effect of fertilizer and mulch as black polythene (F3M3) compared to control (F0M0). So, mineral fertilizer and vermicompost with black polythene had the best performance considering the growth and yield of cabbage. Research limitations: Evaluation of different ratios of organic and inorganic fertilizers with mulching could have better outcome or findings of this work. Originality/Value: Combination of organic and inorganic fertilizers with black polythene as mulch have showed the highest growth and yield outcome of cabbage compared to other treatments combinations. This work has the opportunity to reduce the application of inorganic fertilizer to improve the soil health and environment in long run.

2.2 Effect of GA_3

Chaurasiy *et al.* (2014) conducted an experiment to study the response of cabbage cv. Pride of India to foliar application of PGRs namely GA_3 and NAA with different concentrations. The experiment was laid out in Randomized block design with three replications and seven treatments, the treatments comprised of three levels of each PGRs namely GA_3 (30, 60, 90 ppm) and NAA (40, 80, 120 ppm) along with control. Foliar spray of GA_3 and NAA was given at 30 and 45 DAT of cabbage. Looking to the results, it was noticed that GA_3 60 ppm significantly increased the plant height (33.26 cm), number of loose leaves (21.48), plant spread (55.59 cm), stem diameter (3.05 cm), plant weight (2.44 kg), head weight (1.73 kg), head diameter (18.88 cm) as well as head yield (51.26 t/ha) than the other treatments and control. Therefore it may be concluded that foliar application GA3 60 ppm or NAA 80 ppm can be recommended to cabbage growers for obtaining better growth and yield of cabbage.

Roy and Nasiruddin (2011) was conducted the research work to study the effect of GA_3 on growth and yield of cabbage. Single factor experiment consisted of four concentrations of GA_3, viz. 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54 days) and maturity (69.95 days) was recorded with 50 ppm GA_3 and 50 ppm GA_3 gave the highest diameter (23.81 cm) of cabbage head while the lowest diameter (17.89 cm) of cabbage head was found in control condition (0 ppm GA_3) treatment. The application of different concentrations of GA_3 as influenced independently on the growth and yield of cabbage. Significantly the highest yield (104.66 t/ha) was found from 50 ppm GA_3.

Studies on influence of GA, NAA and CCC at three different concentrations on different growth parameters of cabbage (cv. PRIDE OF INDIA) were studied by Lendve *et al.* (2010) and found that application of GA 50 ppm was found significantly superior over most of the treatments in terms of number of the leaves, plant spread, and circumference of stem, left area, fresh and dry weight of the plant, shape index of head, length of root, fresh and dry weight of root. Except treatment GA 75 ppm, which gave better results for days required for head initiation and head maturity.

An experiment was conducted by Yu *et al.* (2010) with ‘8398’ cabbage *(Brassica oleracea var. captata* L.) plants with 7 true leaves and ‘Jingfeng No. 1’ cabbage plants with 9 true leaves were vernalized in incubator. Then, '8398' cabbage plants vernalized for 18 days and ‘ Jingfeng No. 1 ’ cabbage plants vernalized for 21 days were treated by high temperature of 370C for 12 hours to explore the changes of endogenous hormone during devernalization in cabbage. The results showed that: GA_3 content had less changes, IAA content rose and ABA content decreased during devernalization. Compared with CK (vernalization period), GA3 and ABA content decreased significantly, whereas IAA content rose significantly when devernalization ended. Lower GA3 and ABA content, and higher IAA content can benefit the accomplishment of devernalization.

A study was conducted by Roy *et al.* (2010) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to study the effect of starter solution and GA_3 on growth and yield of cabbage. The two factor experiment consisted of four levels of starter solution, viz. 0, 1.0, 1.5 and 2.0% of urea, and four concentrations of GA_3, viz. 0, 25, 50 and 75ppm. The application of starter solution and different concentrations of GA_3 influenced independently and also in combination on the growth and yield of cabbage. The highest yield (104.93 t/ha) was obtained from 1.5% starter solution which was significantly different from other solutions, and the lowest yield (66.86 t/ha) was recorded from the control. Significantly the highest yield (104.66 t/ha) was found from the treatment of 50 ppm GA_3, while the lowest yield (66.56 t/ha) was recorded from control. In case of combined effect, the highest yield of cabbage (121.33 t/ha) was obtained from the treatment combination of 1.5% starter solution + 50 ppm GA_3 followed by 1.5% starter solution + 75 ppm GA_3 (115.22 t/ha), while the lowest yield (57.11 t/ha) was produced by the control treatment. Economic analysis revealed that 1.5% starter solution + 50 ppm GA_3 treatment was the best treatment combination in respect of net return (Tk. 173775/ha) with a benefit cost ratio of 3.52.

Chauhan and Tandel (2009) conducted an experiment in the Agronomy field of N.M. College of Agriculture, Navsari Agricultural University, Navsari during the Rabi season and they showed that spray of GA3 and NAA significantly influenced the performance of growth, yield and quality characters of cabbage. The best plant growth regulator treatments for growth, yield and quality characters of cabbage was GA_3 100 mg l-1 foliar spray at 30 and 45 days after transplanting (DAT) followed by NAA 100 mg l-1 foliar spray at 30 and 45 DAT.

The effect of GA_3 and/or NAA (both at 25, 50, 75 or 100 ppm) on the yield and yield parameters of cabbage (cv. Pride of India) was investigated by Dhengle and Bhosale (2008) in the field at Department of Horticulture, college of Agriculture, Parbhani. The highest yield was obtained with GA3 at 50 ppm followed by NAA at 50 ppm (332.01 and 331.06 q/ha, respectively) Combinations and higher concentrations of plant growth regulators proved less effective.

Yadav *et al.* (2000) was conducted an experiment in Rajasthan, India, during the rabi season of 1996-97 to investigate the effects of NAA at 50, 100 and 150 ppm, gibberellic acid at 50, 100 and 150 ppm and succinic acid at 250, 500 and 750 ppm, applied at 2 spraying levels (1 or 2 sprays at 30 and 60 days after transplanting), on growth and yield of cabbage cv. Golden Acre. The maximum plant height (28.4 cm) and plant spread (0.187 m_2) resulted from 2 sprays with gibberellic acid at 150 ppm. The highest number of open leaves (23.6) and yield (494.78 q/ha) was obtained in the treatment with 2 sprays of gibberellic acid at 100 ppm. Leaf area was highest in 2 sprays of 500 ppm succinic acid.

An experiment was conducted by Dharmender *et al.* (1996) to find out the effect of GA_3 or NAA (both at 25, 50 or 75 ppm) on the yield of cabbage (cv. Pride of India) in the field at Jobner, Rajstan, India. They recorded the highest yield following treatment with GA_3 at 50 ppm followed by NAA at 50 ppm (557.54 and 528.66 q/ha, respectively). They also reported that combination and higher concentrations of plant growth regulators proved less effective and were uneconomic in comparison to control.

The effective concentration of NAA and GA_3 was determined by Islam *et al.* (1993), for promoting growth yield and ascorbic acid content of cabbage. They used 12.5, 25, 50 and 100 ppm of both the NAA and GA_3. They found that ascorbic acid content increased up to 50 ppm when sprayed twice with both the growth regulator, while its content was declined afterwards. They also added that two sprays with 50 ppm GA_3 was suitable both for higher yield and ascorbic acid content of cabbage.

An experiment was conducted by Patil *et al.* (1987) in a field trial with the cultivar Pride applied GA_3 and NAA each at 25, 50, 75 and 100 ppm one month after transplanting. The maximum plant height and head diameter and head weight were noticed with GA_3 at 50 ppm. Significant increase in number of outer and inner leaves was noticed with both GA_3. Head formation and head maturity was 13 and 12 days earlier with 50 ppm GA_3. Maximum number of loose leaves and maximum yield (63.83 t/ha) were obtained with 50 ppm GA_3.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2018 to March 2019 to study the growth and yield of cabbage as influenced by GA_3 and mulching. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is90°33´ E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.4 Test crop

The test crop; green cabbage was used for the experiment. The variety, Atlas-70 was considered for the present study.

3.5 Experimental details

3.5.1 Treatments

The experiment comprised of two factors.

Factor A: Mulching - 3 types

1. M_0 = Control (No mulching)
2. M_1 = Polythene mulch
3. M_2 = Straw mulch

Factor B: GA_3 - 4 levels

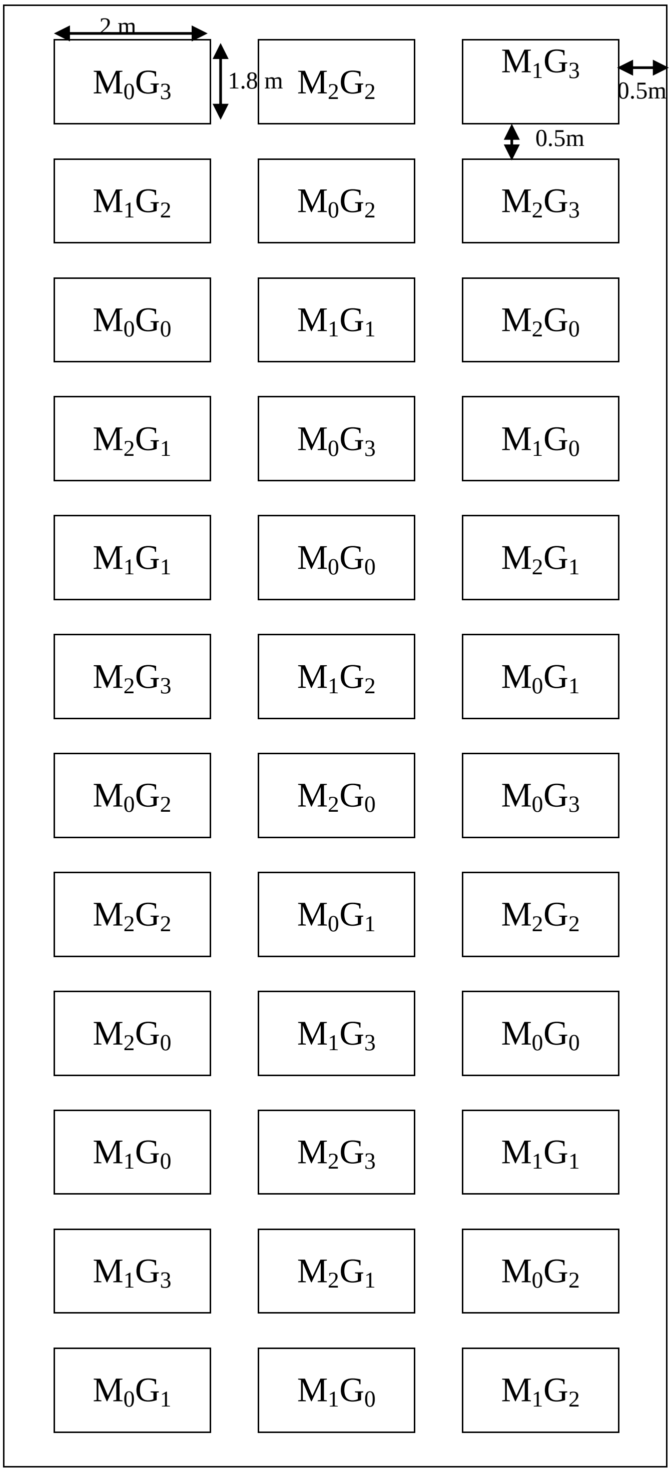
1. G_0 = Control (0 ppm GA_3)
2. G_1 = 80 ppm GA_3
3. G_2 = 100 ppm GA_3
4. G_3 = 120 ppm GA_3

Treatment combinations – There were twelve treatment combinations are as follows:

M_0G_0, M_0G_1, M_0G_2, M_0G_3, M_1G_0, M_1G_1, M_1G_2, M_1G_3, M_2G_0, M_2G_1, M_2G_2 and M_2G_3.

3.5.2 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of mulching and GA_3. Mulching consisted of 3 different treatments and GA_3 consisted of 4 different treatments. The 12 treatment combinations of the experiment were assigned. The area of the experimental plot was divided into three equal blocks. Each block was divided into 12 plots where 12 treatment combinations were allotted at random. The



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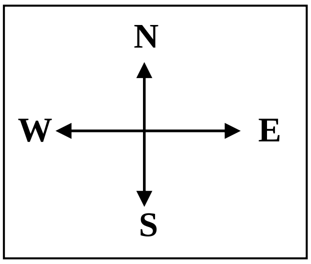

Factor A: Mulching - 3 types

1. M_0 = Control (No mulch)
2. M_1 = Polythene mulch
3. M_2 = Straw mulch

Factor B: GA_3 - 4 levels

1. G_0 = Control (0 ppm GA_3)
2. G_1 = 80 ppm GA_3
3. G_2 = 100 ppm GA_3
4. G_3 = 120 ppm GA_3

Plot size: 1.8 × 2 m^2

Age of seedlings: 30 days

Plant spacing: 50 × 60 cm^2

Layout of the experimental plot

size of each unit plot 1.8m × 2m. The distance between blocks and plots were 0.5m and 0. 5m respectively.

3.6 Variety used and seed collection

The cabbage variety; Atlas-70 was used for the present study. The seeds of this variety were collected from Siddik Bazar, Dhaka.

3.7 Raising of seedlings

The land selected for nursery beds were well drained and were sandy loam type soil. The area was well prepared and converted into loose friable and dried mass to obtain fine tilth. All weeds and dead roots were removed and the soil was mixed with well rotten cowdung at the rate of 5 kg/bed. Each seed bed size was 3m × 1m raised above the ground level. One seed beds was prepared for raising the seedlings. Ten (10) grams of seeds were sown in the seed bed on 10 October, 2018. After sowing, the seeds were covered with light soil. Complete germination of the seeds took place with 5 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. No chemical fertilizer was used in the seed bed.

3.8 Preparation of the main field

The plot selected for the experiment was opened in the last week of October, 2018 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting. The land operation was completed on 2nd November 2018. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.9 Fertilizers and manure application

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of BARI (2017).

Nutrients	Manures/fertilizers	Doses ha^{-1}
-	Cowdung	10 ton
N	Urea	350 kg
P	TSP	250 kg
K	MoP	300 kg
B	Borax	4 kg

The total amount of cowdung, TSP and MOP was applied as basal dose at the time of land preparation. The total amount of urea was applied in three installments at 10, 30 and 50 days after transplanting.

3.10 Transplanting of seedlings

Healthy and uniform sized 30 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 4th November, 2018 maintaining a spacing of 45 cm × 60 cm. There were 12 plants transplanted in each plot. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Shading was provided by piece of banana leaf sheath for three days to protect the seedlings from the direct sun. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.11 Preparation and application of GA_3

Plant growth regulator Gibberellic Acid (GA_3) was collected from Hatkhola Road, Dhaka. A 1000 ppm stock solution of GA_3 was prepared by dissolving 1 g of it in a small quantity of ethanol prior to dilution with distilled water in one litre of volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e. 80 ml of this stock solution was diluted in 1 litre of distilled water to get 80 ppm GA_3 solution. In a similar way, 100 ppm stock solutions were diluted to 1 litre of distilled water to get 100 ppm solution. Again, 120 ppm stock solutions were diluted to 1 litre of distilled water to get 120 ppm solution. Control solution also prepared only by adding a small quantity of ethanol with distilled water. GA_3 as per treatment were applied at four times 15, 30 and 45, 60 days after transplanting by a mini hand sprayer.

3.12 Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the cabbage.

3.12.1 Gap filling and weeding

When the seedlings were established, the soil around the base of each seedling was crushed. A few gaps filling were done by healthy plants from the border whenever it was required. Weeds of different types were controlled manually as and when necessary.

3.12.2 Irrigation

Light over-head irrigation was provided with a watering can to the plots immediately after transplanting and it was continued for a week for rapid and well establishment of the transplanted seedlings. Irrigation was also applied as and when necessary.

3.12.3 Plant protection

The crop was protected from the attack of insect-pest by spraying Melathion 45 EC at the rate of 2 ml/L water. The insecticide application was done fortnightly as a matter of routine work from transplanting up to the end of head formation.

3.13 Harvesting

Harvesting of the cabbage was not possible on a certain or particular date because the head initiation as well as head at marketable size in different plants were not uniform. Only the compact marketable heads were harvested with fleshy stalk by using as sharp knife. The crop was harvested depending upon the maturity of the crop. Before harvesting of the cabbage head, compactness of the head was tested by pressing with thumbs. Harvesting was done manually. Proper care was taken during harvesting period to prevent damage of cabbage head. Harvesting was started from 20 February, 2019 and completed by 2nd March, 2019.

3.14 Data Collection and Recording

Ten plants were selected randomly from each unit plot for recording data on crop parameters and the yield of grain and straw were taken plot wise. The following parameters were recorded during the study:

3.14.1 Growth parameters

1. Plant height (cm)
2. Number of loose leaves plant^{-1}
3. Leaf length (cm)
4. Leaf breadth (cm)
5. Plant spread (cm)

3.14.2 Yield contributing parameters

1. % dry matter of head
2. Head diameter (cm)
3. Thickness of head (cm)
4. Stem length at harvest (cm)
5. % dry matter of stem

3.14.3 Yield parameters

1. Fresh weight plant^{-1} (g)
2. Gross yield plot^{-1} (kg)
3. Gross yield ha^{-1} (t)
4. Marketable yield plant^{-1} (g)
5. Marketable yield plot^{-1} (kg)
6. Marketable yield ha^{-1} (t)

3.14.4 Economic analysis

1. Total cost of production
2. Gross return (Tk. ha^{-1})
3. Net return (Tk. ha^{-1})
4. Benefit Cost Ratio (BCR)

3.15 Procedure of recording data

3.15.1 Growth parameters

Plant height (cm)

Plant height was recorded at 30 and 50 days after transplanting (DAT) and at harvest of crop duration. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured in centimeter (cm) from the ground level to the tip of the leaves.

Number of loose leaves plant^{-1}

Number of loose leaves plant^{-1} was counted at different days after transplanting (DAT) of crop duration. Leaves number plant^{-1} was recorded from pre selected 5 plants by counting all leaves from each plot and mean was calculated. It was recorded at 30 and 50 DAT and at harvest.

Leaf length (cm)

Leaf length was measured by using a meter scale. The measurement was taken from base of leaf to tip of the petiole. Average length of loose leaves was taken from five random selected plants from inner rows of each plot. Data was recorded at 30 and 50 DAT and at harvest. Mean was expressed in centimeter (cm).

Leaf breadth (cm)

Leaf breadth was recorded as the average of five leaves selected at random from the plant of inner rows of each plot at 30 and 50 DAT and at harvest. Thus mean was recorded and expressed in centimeter (cm).

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 and 50 DAT and at harvest and mean value was counted and was expressed in centimeter (cm).

3.15.2 Yield contributing parameters

Percent (%) dry matter of head

At first head from selected plant were collected, cut into pieces and 100 g fresh cabbage head was taken and was dried under sunshine for a few days. Samples were then dried in an oven at 70°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken and expressed as percent (%) dry matter content of cabbage head using the following fourmula

$$\% \text{ Dry matter} = \frac{\text{Fresh weight of cabbage head (g)}}{\text{Oven dry weight of cabbage head (g)}} \times 100$$

Head diameter (cm)

Diameter of head was measured from five plants when it was harvested and then mean was recorded and expressed in centimeter (cm).

Thickness of head (cm)

Thickness of head was measured from five plants when it was harvested and then mean was recorded and expressed in centimeter (cm).

Stem length at harvest (cm)

Stem length was recorded as the average of five selected plants from base to top of stem at random at the time of harvest in inner rows of each plot. Thus mean was recorded and expressed in centimeter (cm).

Percent (%) dry matter of stem

At the time of harvest, stem was collected from 5 selected plants and these were cut into pieces and 100 g fresh stem was taken and was dried under sunshine for a few days. Samples were then dried in an oven at 70°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken and expressed as percent (%) dry matter content of stem. Dry weight of stem was measured by the following formula

$$\% \text{ Dry matter} = \frac{\text{Fresh weight of cabbage stem (g)}}{\text{Oven dry weight of cabbage stem (g)}} \times 100$$

3.15.3 Yield parameters

Fresh weight plant^{-1} (g)

At the time of harvest of plant, whole plant with cabbage head weight was taken from five selected plants after removing soil, roots and other stables from the plants and then mean was recorded and expressed in gram (g). Fresh weight per plant was calculated by the following formula:

$$\% \text{ Dry matter} = \frac{\text{Total Fresh weight of 5 plants (g)}}{5}$$

Gross yield plot^{-1} (kg)

Gross yield per plot was recorded by multiplying average gross weight of head per plant with total number of plant within a plot and was expressed in kilogram.

Gross yield ha^{-1} (t)

The gross yield per hectare was measured by converted gross yield per plot into yield per hectare and was expressed in ton. Yield included with folded and unfolded leaves of cabbage.

Marketable yield plant^{-1} (g)

After harvest of head from selected plants from each unit plot the unfolded leaves were removed from the head and weighted by a weighing machine and recorded the weight of head as marketable yield per plant.

Marketable yield plot^{-1} (kg)

Marketable yield per plot was recorded by multiplying average marketable yield weight of head per plant with total number of plant within a plot and was expressed in kilogram. Marketable yield included only the yield of marketable head.

Marketable yield ha^{-1} (t)

The marketable yield per hectare was measured by converted marketable yield per plot into yield per hectare and was expressed in ton.

3.15.4 Economic analysis

To find out the cost effectiveness of different treatments on cabbage production with GA_3 and boron, the procedure of economic analysis was done in details according to the procedure of (Alam *et al*., 1989).

Total cost of production

All the material and non-material input cost, interest on fixed capital of land and miscellaneous cost were considered for calculating the total cost of production. Total cost of production (input cost, overhead cost), gross return, net return and BCR are presented in Appendix VIII.

Gross return (Tk. ha^{-1})

Gross return was calculated on the basis of mature cabbage head sale. The price of cabbage was assumed to be Tk. 12.00/kg basis of current market value of Kawran Bazar, Dhaka at the time of harvesting.

Net return

Net return was calculated by deducting the total production cost from gross income for each treatment combination.

Benefit cost ratio (BCR)

The economic indicator BCR was calculated by the following formula for each treatment combination.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income per hectare}}{\text{Total cost of production per hectare}}$$

3.16 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the growth and yield of cabbage as influenced by GA_3 and mulching. Data on different growth and yield of cabbage were recorded. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

Due to application of different levels of mulch materials showed significant variation on plant height of cabbage at different days after transplanting except at 30 DAT (Fig. 1 and Appendix IV). The highest plant height (24.06, 35.69 and 45.87 cm at 30, 50 DAT and at harvest, respectively) was recorded from the treatment M_1 (polythene mulch) which was significantly different from other treatments followed by M_2 (straw mulch) whereas the lowest plant height (23.03, 33.17 and 42.63 cm at 30, 50 DAT and at harvest, respectively) was found from the treatment M_0 (control condition). The result on plant height of cabbage obtained from the present findings was similar with the findings of Farjana and Islam (2019) and Chawla (2006) who reported that mulching had contribution on increased plant height through water and nutrient conservation.

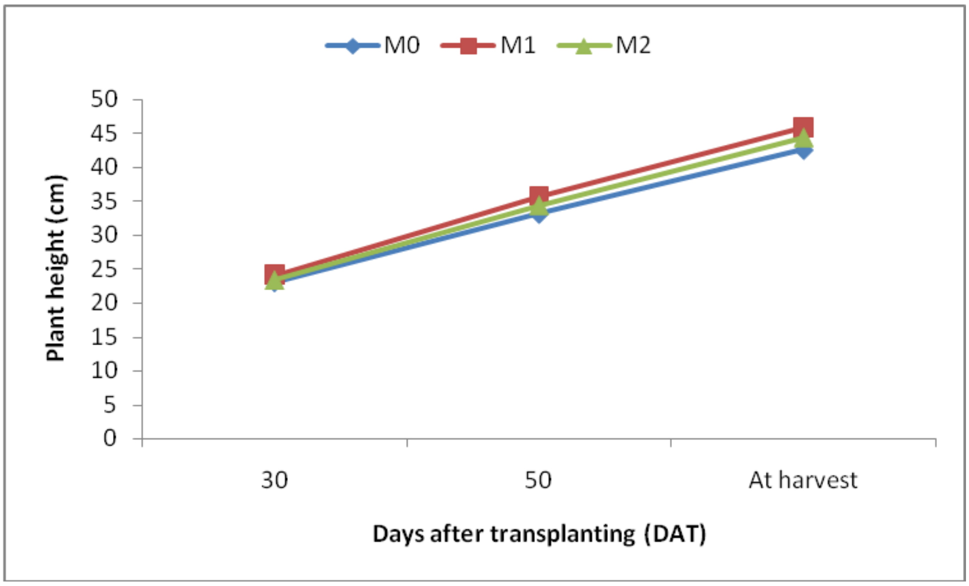

Fig. 1. Plant height of cabbage as influenced by mulching ($LSD_{0.05}$ = 1.821, 2.012 and 1.023 at 30, 50 and DAT and at harvest, respectively)

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

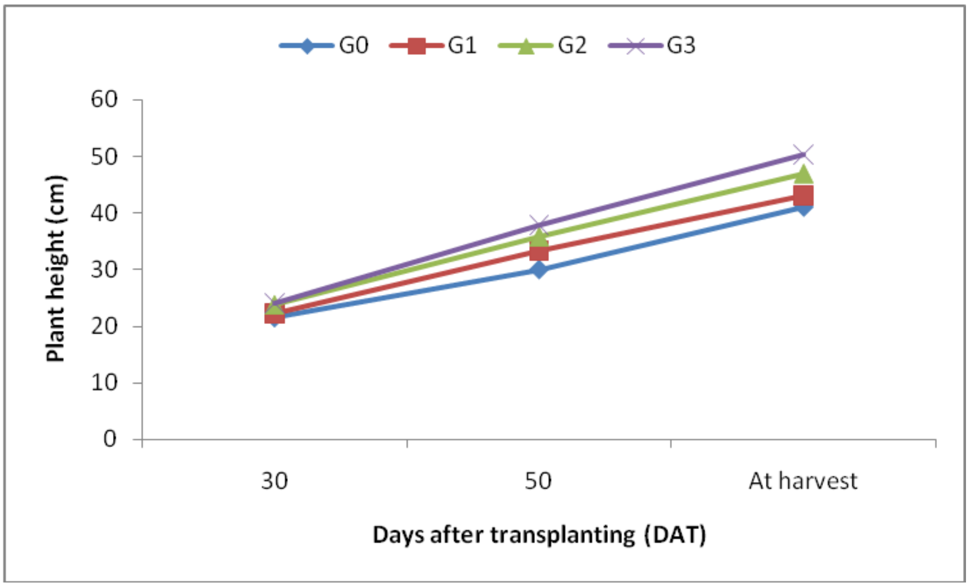

Fig. 2. Plant height of cabbage as influenced by GA_3 ($LSD_{0.05}$ = 0.2092, 1.775 and 1.894 at 30, 50 and DAT and at harvest, respectively)

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

Statistically significant variation was recorded on plant height of cabbage due to different levels of gibberellic acid at different DAT (Fig. 2 and Appendix IV). The highest plant height (24.05, 37.83 and 50.30 cm at 30, 50 DAT and at harvest, respectively) was observed from the treatment G_3 (120 ppm GA_3) which was significantly different from other treatments and followed by G_2 (100 ppm GA_3). The lowest plant height (21.60, 30.06, 41.05 cm at 30, 50 DAT and at harvest, respectively) was obtained from the control treatment G_0 (0 ppm GA_3). Similar result trends of results was also observed by Chaurasiy *et al.* (2014) and Yadav *et al.* (2000) who reported that higher doses of GA3 contributed to higher plant height.

Combined effect of different mulching treatment and gibberellic acid showed significant differences on plant height of cabbage (Table 1 and Appendix IV). The highest plant height (25.51, 39.37 and 51.59 cm at 30, 50 DAT and at harvest, respectively) was observed from the treatment combination of M_1G_3 which was statistically similar with the treatment combination of M_2G_3. The lowest plant height (21.30, 29.03 and 39.45 cm at 30, 50 DAT and at harvest, respectively) was obtained from the treatment combination of M_0G_0 (control treatment).

Table 1. Plant height of cabbage as influenced by GA_3 and mulching

Treatments	Plant height		
	30 DAT	50 DAT	At harvest
M_0G_0	21.30 g	29.03g	39.45i
M_0G_1	22.09f	32.52ef	42.57gh
M_0G_2	23.18d	34.63cd	46.30de
M_0G_3	24.01c	35.94c	48.24cd
M_1G_0	21.96f	31.35f	42.04h
M_1G_1	22.58e	34.01d	45.37ef
M_1G_2	24.66b	37.50b	49.30bc
M_1G_3	25.51a	39.37a	51.59a
M_2G_0	21.42g	29.10g	42.03h
M_2G_1	22.21ef	33.61de	44.10fg
M_2G_2	23.34d	35.50c	47.25de
M_2G_3	25.33a	38.29ab	50.44ab
$LSD_{0.05}$	0.254	1.262	1.902
CV(%)	6.62	8.76	9.96

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

4.1.2 Number of loose leaves plant^{-1}

Different levels of mulch materials showed significant variation on number of loose leaves plant^{-1} of cabbage at different DAT except at 30 DAT (Fig. 3 and Appendix V). The highest number of loose leaves plant^{-1} (9.30, 12.72 and 17.99 at 30, 50 DAT and at harvest, respectively) was recorded from the treatment M_1 (polythene mulch) which was significantly different from other treatments and followed by M_2 (straw mulch). The lowest number of loose leaves plant^{-1} (8.58, 11.72 and 16.87 at 30, 50 DAT and at harvest, respectively) was found from the treatment M_0 (control condition). Farjana and Islam (2019) showed similar results with the present study.

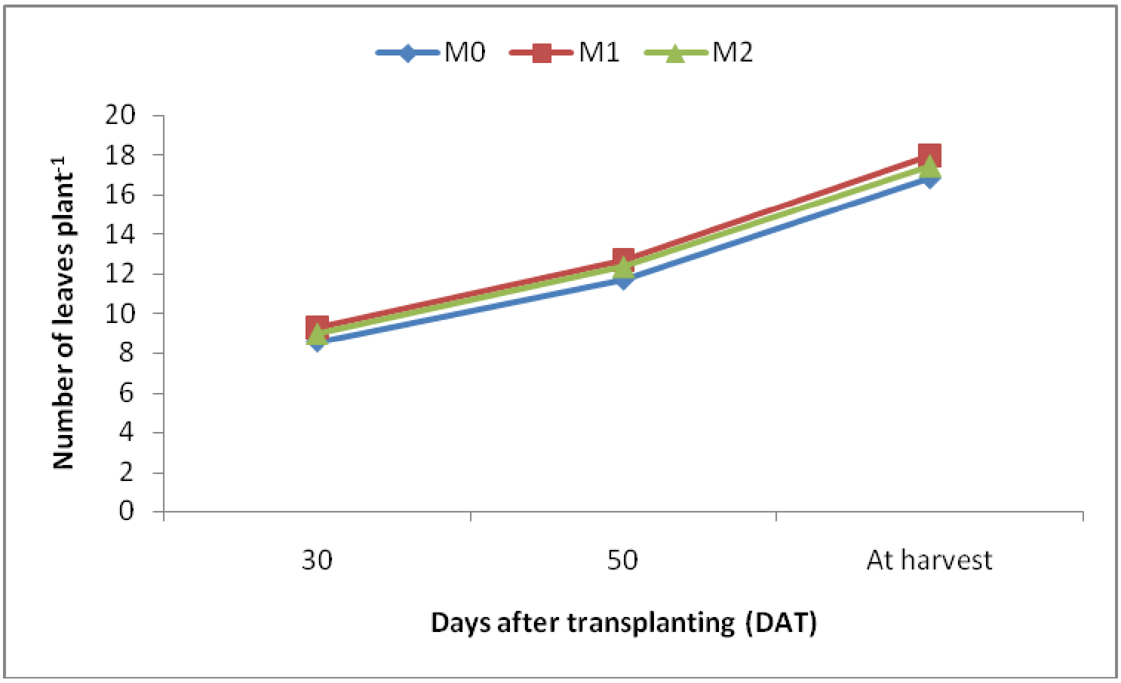

Fig. 3. Leaf number plant^{-1} of cabbage as influenced by mulching

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

Number of loose leaves plant^{-1} of cabbage varied significantly due to different levels of gibberellic acid at different DAT (Fig. 4 and Appendix V). The highest number of loose leaves plant^{-1} (10.41, 14.40 and 19.80 at 30, 50 DAT and at harvest, respectively) was observed from G_2 (100 ppm GA_3) which was significantly different from other treatments at all observations. The lowest number of loose leaves plant^{-1} (7.74, 9.81 and 15.04 at 30, 50 DAT and at harvest, respectively) was obtained from the control treatment G_0 (0 ppm GA_3). The result obtained from the present experiment was similar to the findings of Chaurasiy *et al.* (2014).

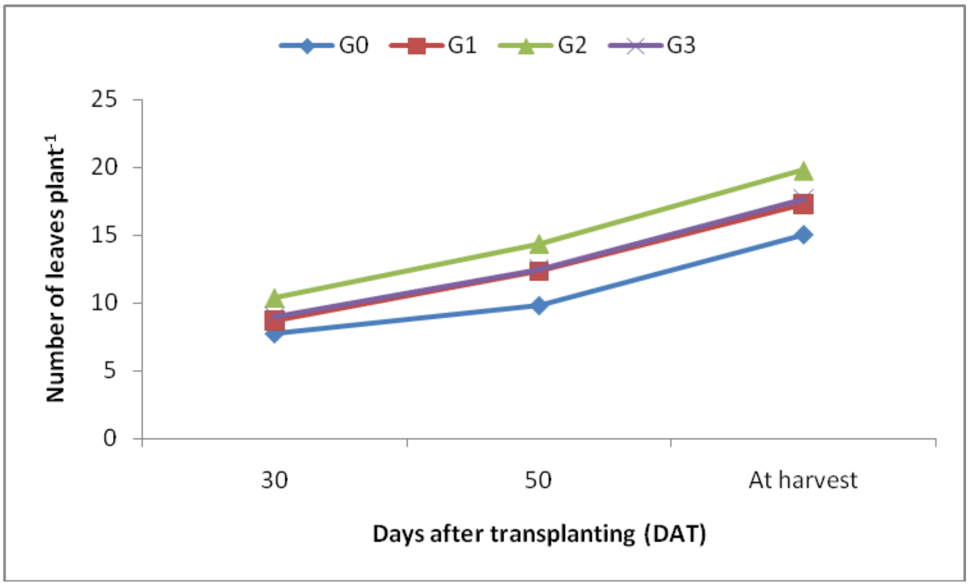

Fig. 4. Leaf number plant^{-1} of cabbage as influenced by GA_3

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

Significant variation on number of loose leaves plant^{-1} of cabbage showed at different days after transplanting due to application of different levels of mulching and gibberellic acid (Table 2and Appendix V). The highest number of loose leaves plant^{-1} (10.64, 14.88 and 20.40 at 30, 50 DAT and at harvest, respectively) was observed from the treatment combination of M_1G_2 which was statistically identical to the treatment combination of M_2G_2. The lowest number of loose leaves plant^{-1} (7.64, 9.42 and 14.80 at 30, 50 DAT and at harvest, respectively) was obtained from the treatment combination of M_0G_0 which was statistically identical to the treatment combination of M_1G_0 and M_2G_0.

Table 2. Leaf number $plant^{-1}$ of cabbage as influenced by GA_3 and mulching

Treatments	Number of loose leaves $plant^{-1}$		
	30 DAT	50 DAT	At harvest
M_0G_0	7.640 g	9.420 e	14.80 e
M_0G_1	8.000 fg	11.60 d	16.44 d
M_0G_2	10.12 ab	13.85 bc	18.88 b
M_0G_3	8.570 de	12.00 d	17.36 cd
M_1G_0	7.880 fg	10.14 e	15.27 e
M_1G_1	9.760 bc	13.60 bc	18.54 b
M_1G_2	10.64 a	14.88 a	20.40 a
M_1G_3	8.920 d	12.24 d	17.75 bc
M_2G_0	7.720 fg	9.880 e	15.06 e
M_2G_1	8.220 ef	11.77 d	16.84 cd
M_2G_2	10.48 a	14.46 ab	20.12 a
M_2G_3	9.440 c	13.33 c	17.92 bc
$LSD_{0.05}$	0.4966	0.9367	1.082
CV(%)	4.93	6.51	7.66

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

4.1.3 Leaf length (cm)

Significant variation was found on leaf length of cabbage at different days after transplanting except 30 DAT (Table 3 and Appendix VI). The highest leaf length (23.20, 28.57 and 31.00 cm at 30, 50 DAT and at harvest, respectively) was recorded from the treatment M_1 (polythene mulch) which was significantly different from other treatments. The lowest leaf length (22.50, 27.98 and 29.70 cm at 30, 50 DAT and at harvest, respectively) was found from the treatment M_0 (control treatment) which was statistically identical with M_2 (straw mulch).

Statistically significant variation was recorded for plant of cabbage due to different levels of gibberellic acid at different growth stages (Table 3 and Appendix VI). The highest leaf length (24.10, 29.84 and 33.04 cm at 30, 50 DAT and at harvest, respectively) was observed in G_3 (120 ppm GA_3) treatment which was significantly different from other treatments. The lowest leaf length (21.49, 25.80 and 27.66 cm at 30, 50 DAT and at harvest, respectively) was obtained from the control treatment G_0 (0 ppm GA_3).

Table 3. Leaf length of cabbage as influenced by mulching and GA_3

Treatments	Leaf length (cm)		
	30 DAT	50 DAT	At harvest
Effect of mulching			
M_0	22.50	27.98	29.70 b
M_1	23.20	28.57	31.00 a
M_2	22.84	27.58	30.24 b
$LSD_{0.05}$	1.259	1.048	0.5526
CV(%)	9.84	7.60	9.39
Effect of GA_3			
G_0	21.49 b	25.80 c	27.66 d
G_1	22.40 b	27.56 b	29.18 c
G_2	23.40 a	28.98 a	31.37 b
G_3	24.10 a	29.84 a	33.04 a
$LSD_{0.05}$	0.9840	0.9932	1.037
CV(%)	9.84	7.60	9.39
Combined effect of mulching and GA_3			
M_0G_0	21.32 h	25.62 g	27.47 g
M_0G_1	22.12 fg	27.10 f	28.73 f
M_0G_2	22.92 de	28.52 de	30.48 d
M_0G_3	23.64 bc	29.07 cd	32.14 c
M_1G_0	21.64 gh	26.00 g	27.92 g
M_1G_1	22.71 ef	28.21 e	29.64 e
M_1G_2	23.88 bc	29.64 bc	32.72 bc
M_1G_3	24.57 a	30.44 a	33.72 a
M_2G_0	21.52 gh	25.77 g	27.60 g
M_2G_1	22.36 ef	27.36 f	29.18 ef
M_2G_2	23.40 cd	28.78 de	30.90 d
M_2G_3	24.10 ab	30.00 ab	33.27 ab
$LSD_{0.05}$	0.6011	0.6245	0.8050
CV(%)	9.84	7.60	9.39

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

Combined effect of different mulching treatment and gibberellic acid showed significant differences on leaf length of cabbage at different growth stages (Table 3 and Appendix VI). The highest leaf length (24.57, 30.44 and 33.72 cm at 30, 50 DAT and at harvest, respectively) was observed from the treatment combination of M_1G_3 which was statistically similar with the treatment combination of M_2G_3 whereas the lowest leaf length (21.32, 25.62 and 27.47 cm at 30, 50 DAT and at harvest, respectively) was obtained from the treatment combination of M_0G_0 which was statistically identical with the treatment combination of M_1G_0 and M_2G_0.

4.1.4 Leaf breadth (cm)

Significant influence was recorded for leaf breadth of cabbage at different growth stages except at 30 DAT as affected by different mulching treatment (Table 4 and Appendix VII). The highest leaf breadth (14.93, 18.24 and 19.43 cm at 30, 50 DAT and at harvest, respectively) was recorded from the treatment M_1 (polythene mulch) which was statistically identical with M_2 (straw mulch) whereas the lowest leaf breadth (14.06, 17.02 and 18.50 cm at 30, 50 DAT and at harvest, respectively) was found from the treatment M_0 (control condition).

Leaf breadth of cabbage varied significantly due to different levels of gibberellic acid at different growth stages (Table 4 and Appendix VII). The highest leaf breadth (16.51, 21.18 and 23.20 cm at 30, 50 DAT and at harvest, respectively) was observed from the treatment G_2 (100 ppm GA_3) which was significantly different from other treatments and followed by G_1 (80 ppm GA_3) and G_3 (120 ppm GA_3). The lowest leaf breadth (12.17, 14.81 and 16.13 cm at 30, 50 DAT and at harvest, respectively) was obtained from the control treatment G_0 (0 ppm GA_3).

Variation on leaf breadth of cabbage showed significant variation at different DAT as influenced by different levels of mulching and gibberellic acid combination (Table 4 and Appendix VII). The highest leaf breadth (16.78, 21.48 and 23.62 cm at 30, 50 DAT and at harvest, respectively) was observed from the treatment combination of M_1G_2 which was statistically identical with the treatment combination of M_2G_2. The lowest leaf breadth (11.92, 14.64 and

15.94 cm at 30, 50 DAT and at harvest, respectively) was obtained from the treatment combination of M_0G_0 which was statistically identical with M_1G_0 and M_2G_0.

Table 4. Leaf breadth of cabbage as influenced by GA_3 and mulching

Treatments	Leaf breadth (cm)		
	30 DAT	50 DAT	At harvest
Effect of mulching			
M_0	14.06	17.02 b	18.50 b
M_1	14.93	18.24 a	19.43 a
M_2	14.53	17.70 a	18.97 a
$LSD_{0.05}$	0.9705	0.6386	0.4676
CV(%)	7.86	8.44	8.91
Effect of GA_3			
G_0	12.17 c	14.81 c	16.13 c
G_1	14.47 b	17.02 b	18.17 b
G_2	16.51 a	21.18 a	23.20 a
G_3	14.87 b	17.59 b	18.35 b
$LSD_{0.05}$	0.2817	1.057	1.117
CV(%)	7.86	8.44	8.91
Combined effect of mulching and GA_3			
M_0G_0	11.92 h	14.64 f	15.94 g
M_0G_1	13.66 g	15.88 e	17.44 f
M_0G_2	16.18 ab	20.83 a	22.72 b
M_0G_3	14.46 ef	16.72 d	17.88 ef
M_1G_0	12.42 h	14.92 f	16.33 g
M_1G_1	15.64 bc	18.75 b	19.36 c
M_1G_2	16.78 a	21.48 a	23.62 a
M_1G_3	14.87 de	17.80 c	18.40 de
M_2G_0	12.18 h	14.88 f	16.11 g
M_2G_1	14.12 fg	16.44 de	17.72 f
M_2G_2	16.57 a	21.24 a	23.27 a
M_2G_3	15.27 cd	18.26 bc	18.78 d
$LSD_{0.05}$	0.5963	0.6961	0.5487
CV(%)	7.86	8.44	8.91

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

4.1.5 Plant spread (cm)

Significant influence was recorded for plant spread of cabbage at different growth stages as affected by different mulching treatment (Table 5 and Appendix IX). The highest plant spread (19.08, 43.75 and 54.40 cm at 30, 50 DAT and at harvest, respectively) was recorded from the treatment M_1 (polythene mulch) followed by M_2 (straw mulch) whereas the lowest plant spread (17.40, 40.50 and 51.50 cm at 30, 50 DAT and at harvest, respectively) was found from the treatment M_0 (control condition). Similar trend of result was also observed by Bhardwaj (2011).

Plant spread of cabbage varied significantly due to different levels of gibberellic acid at different growth stages (Table 5 and Appendix VIII). The highest plant spread (23.53, 48.52 and 58.75 cm at 30, 50 DAT and at harvest, respectively) was observed from the treatment G_2 (100 ppm GA_3) which was significantly different from other treatments and followed by G_1 (80 ppm GA_3) and G_2 (100 ppm GA_3). The lowest plant spread (14.80, 35.17 and 47.90 cm at 30, 50 DAT and at harvest, respectively) was obtained from the control treatment G_0 (0 ppm GA_3). The result obtained from the present experiment was similar with the findings of Yadav *et al.* (2000).

Variation on plant spread of cabbage showed significant variation at different growth stages as influenced by different levels of mulching and gibberellic acid combination (Table 5 and Appendix VIII). The highest plant spread (23.52, 48.64 and 59.66 cm at 30, 50 DAT and at harvest, respectively) was observed from the treatment combination of M_1G_2 which was statistically identical to the treatment combination of M_2G_2. The lowest plant spread (14.41, 34.01 and 47.23 cm at 30, 50 DAT and at harvest, respectively) was obtained from the treatment combination of M_0G_0 which was statistically identical with the treatment combination of M_1G_0 and M_2G_0.

Table 5. Plant spread of cabbage as influenced by GA_3 and mulching

Treatments	Plant spread (cm)		
	30 DAT	50 DAT	At harvest
Effect of mulching			
M_0	17.40c	40.50c	51.80c
M_1	19.08a	43.75a	54.40a
M_2	18.69b	42.28b	53.23b
$LSD_{0.05}$	0.5736	1.084	1.792
Effect of GA_3			
G_0	14.80c	35.17c	47.90c
G_1	17.66b	41.73b	52.70b
G_2	23.53a	48.52a	58.75a
G_3	18.99b	43.48b	53.25b
$LSD_{0.05}$	1.623	1.934	1.907
Combined effect of mulching and GA_3			
M_0G_0	14.41g	34.01h	47.23f
M_0G_1	16.05f	37.85g	51.15e
M_0G_2	21.81b	46.23b	56.39b
M_0G_3	17.56e	41.28ef	52.38de
M_1G_0	14.91g	34.88h	48.40f
M_1G_1	20.20c	45.54bc	55.19bc
M_1G_2	24.58a	49.04a	60.99a
M_1G_3	19.30d	42.92de	53.26cde
M_2G_0	14.80g	34.53h	48.02f
M_2G_1	16.41f	39.73f	50.66e
M_2G_2	23.92a	48.12a	59.14a
M_2G_3	19.94cd	44.02cd	53.95cd
$LSD_{0.05}$	0.815	1.814	06.78
CV(%)	7.85	9.81	10.82

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

4.2 Yield contributing parameters

4.2.1 Percent (%) dry matter of head

Significant variation was recorded on % dry matter of cabbage head as affected by different mulching treatment (Table 6 and Appendix IX). The highest % dry matter (11.80%) was found from the treatment M_1 (polythene mulch) which was significantly different from other treatments and followed by M_2 (straw mulch) whereas the lowest % dry matter (11.05%) was recorded from the treatment M_0 (control condition). Saifullah *et al*. (1996) and Crusciol *et al*. (2005) also found similar result with the present study.

Statistically significant difference among the treatment was found on % dry matter of cabbage head as influenced by different levels of gibberellic acid (Table 6 and Appendix IX). The highest % dry matter (12.77%) was obtained from the treatment G_2 (100 ppm GA_3) followed by G_3 (120 ppm GA_3) whereas the lowest % dry matter (10.00%) was achieved from the control treatment G_0 (0 ppm GA_3). Similar result was also observed by Lendve *et al.* (2010).

Combined effect of different levels of mulching and gibberellic acid showed significant variation on % dry matter of cabbage head (Table 6 and Appendix IX). The highest % dry matter (12.98%) was recorded from the treatment combination of M_1G_2 which was statistically similar with the treatment combination of M_0G_2, M_1G_1 and M_2G_2. The lowest % dry matter (9.77%) was found from the treatment combination of M_0G_0 which was statistically similar with M_1G_0 and M_2G_0.

4.2.2 Head diameter (cm)

Significant variation was recorded on head diameter of cabbage as affected by different mulching treatment (Table 6 and Appendix IX). The highest head diameter (13.20 cm) was found from the treatment M_1 (polythene mulch) which was significantly different from other treatments whereas the lowest head diameter (12.50 cm) was recorded from the treatment M_0 (control condition). The result obtained from the present experiment was similar with the findings of Saifullah *et al*. (1996).

Statistically significant difference was found on head diameter of cabbage due to application of different levels of gibberellic acid (Table 6 and Appendix IX). The highest head diameter (14.29 cm) was obtained from the treatment G_2 (100 ppm GA_3) followed by G_1 (80 ppm GA_3) and G_3 (120 ppm GA_3) whereas the lowest head diameter (11.05 cm) was achieved from the control treatment G_0 (0 ppm GA_3). Similar trend of result was also observed by Chaurasiy *et al.* (2014) who reported that GA_3 at 60 ppm significantly increased head diameter.

Combined effect of different levels of mulching and gibberellic acid showed significant variation on head diameter of cabbage (Table 6 and Appendix IX). The highest head diameter (14.55 cm) was recorded from the treatment combination of M_1G_2 which was statistically identical to the treatment combination of M_0G_2 and M_2G_2. The lowest head diameter (10.35 cm) was found from the treatment combination of M_0G_0 which was statistically identical with the treatment combination of M_1G_0 and M_2G_0.

4.2.3 Thickness of head (cm)

Significant variation was recorded on thickness of head of cabbage as affected by different mulching treatment (Table 6 and Appendix IX). The highest thickness of head (14.48 cm) was found from the treatment M_1 (polythene mulch) followed by M_2 (straw mulch). The lowest plant (13.75 cm) was recorded from the treatment M_0 (control condition). Saifullah *et al*. (1996) also found similar result which supported the present study.

Statistically significant difference among the treatment was found on thickness of head of cabbage as influenced by different levels of gibberellic acid (Table 6 and Appendix IX). The highest thickness of head (15.38 cm) was obtained from the treatment G_2 (100 ppm GA_3) which was significantly different from other treatments and followed by G_3 (120 ppm GA_3). The lowest thickness of head (12.50 cm) was achieved from the control treatment G_0 (0 ppm GA_3).

Combined effect of different levels of mulching and gibberellic acid showed significant variation on thickness of head of cabbage (Table Table 6 and Appendix IX). The highest thickness of head (15.30 cm) was recorded from the treatment combination of M_1G_2 which was statistically similar with the treatment combination of M_2G_2. The lowest thickness of head (12.01 cm) was found from the treatment combination of M_0G_0 which was statistically similar to the treatment combination of M_1G_0 and M_2G_0.

Table 6. Yield contributing parameters of cabbage as influenced by GA_3 and mulching

Treatments	Yield contributing parameters				
	% dry matter of head	Head diameter (cm)	Thickness of head (cm)	Stem length at harvest (cm)	% dry matter of stem
Effect of mulching					
M_0	11.05c	12.50c	13.75c	13.00	8.07 c
M_1	11.80a	13.20a	14.48a	13.75	8.47 a
M_2	11.36b	12.72b	14.02b	13.20	8.22 b
$LSD_{0.05}$	0.291	0.2051	0.407	0.447	0.1002
Effect of GA_3					
G_0	10.00d	11.05c	12.50d	12.94c	7.37 c
G_1	11.46c	13.01b	13.80c	13.58b	8.19 b
G_2	12.77a	14.29a	15.38a	14.22a	8.99 a
G_3	11.82b	12.95b	14.36b	13.65b	8.47 b
$LSD_{0.05}$	1.055	0.333	0.4201	0.168	0.3301
Combined effect of mulching and GA_3					
M_0G_0	9.79g	10.95e	12.01g	11.90f	7.26 g
M_0G_1	10.86ef	12.80cd	12.82ef	12.27e	7.88 e
M_0G_2	12.52ab	14.14a	14.80abc	13.05b	8.88 b
M_0G_3	11.53cd	12.43d	13.86d	12.41de	8.24 d
M_1G_0	10.29fg	11.36e	12.40fg	12.06f	7.52 f
M_1G_1	12.53ab	12.94ab	14.60bc	12.91bc	8.73 bc
M_1G_2	12.98a	14.55a	15.30a	13.47a	9.14 a
M_1G_3	11.92bc	13.27bc	14.01d	12.56d	8.52 c
M_2G_0	10.01g	11.08e	12.16g	12.01f	7.33 fg
M_2G_1	11.05de	12.52d	13.04e	12.35e	7.97 e
M_2G_2	12.82a	14.47a	15.12ab	13.31a	8.94 ab
M_2G_3	12.08bc	13.40bc	14.32cd	12.75c	8.64 c
$LSD_{0.05}$	0.631	0.661	0.5672	0.1865	0.204
CV(%)	8.14	7.07	8.08	7.83	8.08

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

4.2.4 Stem length at harvest (cm)

No significant variation was found on stem length of cabbage at harvest as affected by different mulching treatment (Table 6 and Appendix IX). However, the highest plant at harvest (13.35 cm) was found from the treatment M_1 (polythene mulch) whereas the lowest plant at harvest (13.00 cm) was recorded from the treatment M_0 (control condition). Farjana and Islam (2019) also found similar result which supported the present study.

Statistically significant difference was found among the treatment on stem length of cabbage at harvest due to application of different levels of gibberellic acid (Table 6 and Appendix IX). The highest stem length at harvest (14.22 cm) was obtained from the treatment G_2 (100 ppm GA_3) followed by G_3 (120 ppm GA_3) and G_1 (80 ppm GA_3) whereas the lowest stem length at harvest (12.94 cm) was achieved from the control treatment G_0 (0 ppm GA_3).

Combined effect of different levels of mulching and gibberellic acid showed significant variation on stem length of cabbage at harvest (Table 6 and Appendix IX). The highest stem length at harvest (13.47 cm) was recorded from the treatment combination of M_2G_2 which was statistically identical to the treatment combination of M_2G_2. The lowest stem length at harvest (12.94 cm) was found from the treatment combination of M_0G_0 which was statistically identical to the treatment combination of M_1G_0 and M_2G_0.

4.2.5 Percent (%) dry matter of stem

Significant variation was recorded on % dry matter of stem of cabbage as affected by different mulching treatment (Table 6 and Appendix IX). The highest % dry matter of stem (8.47%) was found from the treatment M_1 (polythene mulch) followed by M_2 (straw mulch) whereas the lowest p% dry matter of stem lant (8.07%) was recorded from the treatment M_0 (control condition). Similar result was also observed by Saifullah *et al*. (1996).

Statistically significant difference among the treatment was found on plant of cabbage affected by different levels of gibberellic acid (Table 6 and Appendix X). The highest % dry matter of stem (8.99%) was obtained from the treatment G_2 (100 ppm GA_3) which was significantly different from other treatments and followed by G_1 (80 ppm GA_3) and G_3 (120 ppm GA_3) whereas the lowest % dry matter of stem (7.37%) was achieved from the control treatment G_0 (0 ppm GA_3). Similar result was also observed by Lendve *et al.* (2010).

Combined effect of different levels of mulching and gibberellic acid showed significant variation on % dry matter of stem of cabbage (Table 6 and Appendix IX). The highest % dry matter of stem (9.14%) was recorded from the treatment combination of M_1G_2 which was statistically similar to the treatment combination of M_2G_3. The lowest % dry matter of stem (7.26%) was found from the treatment combination of M_0G_0 which was statistically similar to the treatment combination of M_2G_0.

4.3 Yield parameters

4.3.1 Fresh weight plant^{-1} (g)

Significant variation was recorded on fresh weight plant^{-1} of cabbage as affected by different mulching treatment (Table 7 and Appendix X). It was found that the highest fresh weight plant^{-1} (1473.00 g) was found from the treatment M_1 (polythene mulch) followed by M_2 (straw mulch) whereas the lowest fresh weight plant^{-1} (1384.00 g) was recorded from the treatment M_0 (control condition).

Statistically significant difference among the treatment was found on fresh weight plant^{-1} of cabbage as influenced by different levels of gibberellic acid (Table 7 and Appendix X). The highest fresh weight plant^{-1} (1638.00 g) was obtained from the treatment G_2 (100 ppm GA_3) followed by G_3 (120 ppm GA_3). The lowest fresh weight plant^{-1} (1227.00 g) was achieved from the control treatment G_0 (0 ppm GA_3) which was significantly different from other treatments. Lendve *et al.* (2010) also found similar result with the present study.

Combined effect of different levels of mulching and gibberellic acid showed significant variation on fresh weight plant^{-1} of cabbage (Table 8 and Appendix X). The highest fresh weight plant^{-1} (1673.00 g) was recorded from the treatment combination of M_1G_2 which was statistically identical to the treatment combination of M_2G_2. The lowest fresh weight plant^{-1} (1215.00 g) was found from the treatment combination of M_0G_0 which was statistically similar to the treatment combination of M_2G_0.

4.3.2 Gross yield plot^{-1} (kg)

Significant variation was recorded on gross yield plot^{-1} of cabbage due to use of different mulching treatment (Table 7 and Appendix X). The highest gross yield plot^{-1} (17.68 kg) was found from the treatment M_1 (polythene mulch) followed by M_2 (straw mulch) whereas the lowest gross yield plot^{-1} (16.60 kg) was recorded from the treatment M_0 (control condition).

Statistically significant variation was found on gross yield plot^{-1} of cabbage due to application of different levels of gibberellic acid (Table 7 and Appendix X). The highest gross yield plot^{-1} (19.65 kg) was obtained from the treatment G_2 (100 ppm GA_3) followed by G_1 (80 ppm GA_3) and G_3 (120 ppm GA_3) whereas the lowest gross yield plot^{-1} (14.72 kg) was achieved from the control treatment G_0 (0 ppm GA_3).

Combined effect of different levels of mulching and gibberellic acid showed significant variation on gross yield plot^{-1} of cabbage (Table 8 and Appendix X). The highest gross yield plot^{-1} (20.07 kg) was recorded from the treatment combination of M_1G_2 which was statistically identical with the treatment combination of M_2G_2 whereas the lowest gross yield plot^{-1} (14.57 kg) was found from the treatment combination of M_0G_0 which was statistically identical with the treatment combination of M_1G_0 and M_2G_0.

4.3.3 Gross yield ha^{-1} (t)

Significant variation was recorded on gross yield ha^{-1} of cabbage as affected by different mulching treatment (Table 7 and Appendix X). The highest gross yield ha^{-1} (49.10 t ha^{-1}) was found from the treatment M_1 (polythene mulch) which was significantly different from other treatments followed by M_2 (straw mulch). The lowest gross yield ha^{-1} (46.12 t ha^{-1}) was recorded from the treatment M_0 (control condition).

Statistically significant difference was found on gross yield ha^{-1} of cabbage due to application of different levels of gibberellic acid (Table 7 and Appendix X). The highest gross yield ha^{-1} (54.59 t ha^{-1}) was obtained from the treatment G_2 (100 ppm GA_3) which was significantly different from other treatments followed by G_1 (80 ppm GA_3) and G_3 (120 ppm GA_3) whereas the lowest gross yield ha^{-1} (40.89 t ha^{-1}) was achieved from the control treatment G_0 (0 ppm GA_3).

Combined effect of different levels of mulching and gibberellic acid showed significant variation on gross yield ha^{-1} of cabbage (Table 8 and Appendix X). The highest gross yield ha^{-1} (55.76 t ha^{-1}) was recorded from the treatment combination of M_1G_2 which was statistically identical with the treatment combination of M_2G_2 whereas the lowest gross yield ha^{-1} (40.49 t ha^{-1}) was found from the treatment combination of M_0G_0 which was statistically identical with the treatment combination of M_1G_0 and M_2G_0.

4.3.4 Marketable yield $plant^{-1}$ (g)

Significant variation was recorded on marketable yield $plant^{-1}$ of cabbage as influenced by different mulching treatment (Table 7 and Appendix X). The highest marketable yield $plant^{-1}$ (1291.00 g) was found from the treatment M_1 (polythene mulch) followed by M_2 (straw mulch) whereas the lowest marketable yield $plant^{-1}$ (1208.00 g) was recorded from the treatment M_0 (control condition).

Statistically significant difference among the treatment was found on marketable yield $plant^{-1}$ of cabbage as influenced by different levels of gibberellic acid (Table 7 and Appendix X). The highest marketable yield $plant^{-1}$ (1387.00 g) was obtained from the treatment G_2 (100 ppm GA_3) followed by G_3 (120 ppm GA_3). The lowest marketable yield $plant^{-1}$ (1075.00 g) was achieved from the control treatment G_0 (0 ppm GA_3) which was significantly different from other treatments.

Combined effect of different levels of mulching and gibberellic acid showed significant variation on marketable yield $plant^{-1}$ of cabbage (Table 8 and Appendix X). The highest marketable yield $plant^{-1}$ (1423.00 g) was recorded from the treatment combination of M_1G_2 which was significantly different from other treatment combinations followed by the treatment combination of M_2G_2. The lowest marketable yield $plant^{-1}$ (1039.00 g) was found from the treatment combination of M_0G_0 which was significantly different from other treatment combinations.

Table 7. Yield parameters of cabbage as influenced by GA_3 and mulching

Treatments	Yield parameters				
	Fresh weight $plant^{-1}$ (g)	Gross yield $plot^{-1}$ (kg)	Gross yield ha^{-1} (t)	Marketable yield $plant^{-1}$ (g)	Marketable yield $plot^{-1}$ (kg)
Effect of mulching					
M_0	1384.00 c	16.60 c	46.12 c	1208.00 c	14.49 c
M_1	1473.00 a	17.68 a	49.10 a	1291.00 a	15.49 a
M_2	1433.00 b	17.19 b	47.76 b	1251.00 b	15.02 b
$LSD_{0.05}$	7.678	0.1561	0.5136	8.136	0.4113
CV(%)	7.09	7.08	7.09	9.47	9.46
Effect of GA_3					
G_0	1227.00 d	14.72 c	40.89 c	1075.00 d	12.90 c
G_1	1422.00 c	17.07 b	47.40 b	1251.00 c	15.02 b
G_2	1638.00 a	19.65 a	54.59 a	1387.00 a	16.64 a
G_3	1433.00 b	17.19 b	47.76 b	1287.00 b	15.44 b
$LSD_{0.05}$	9.390	0.3710	1.472	9.032	0.4749
CV(%)	7.09	7.08	7.09	9.47	9.46

In a column means having similar letters arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

4.3.5 Marketable yield plot^{-1} (kg)

Significant variation was recorded on marketable yield plot^{-1} of cabbage as affected by different mulching treatment (Table 7 and Appendix X). The highest marketable yield plot^{-1} (15.49 kg) was found from the treatment M_1 (polythene mulch) followed by M_2 (straw mulch) whereas the lowest marketable yield plot^{-1} (14.49 kg) was recorded from the treatment M_0 (control condition).

Statistically significant difference among the treatment was found on marketable yield plot^{-1} of cabbage as influenced by different levels of gibberellic acid (Table 7 and Appendix X). The highest marketable yield plot^{-1} (16.64 kg) was obtained from the treatment G_2 (100 ppm GA_3) and followed by G_1 (80 ppm GA_3) and G_3 (120 ppm GA_3) whereas the lowest marketable yield plot^{-1} (12.90 kg) was achieved from the control treatment G_0 (0 ppm GA_3).

Combined effect of different levels of mulching and gibberellic acid showed significant variation on marketable yield plot^{-1} of cabbage (Table 8 and Appendix X). The highest marketable yield plot^{-1} (17.07 kg) was recorded from the treatment combination of M_1G_2 which was statistically similar to the treatment combination of M_2G_2 whereas The lowest marketable yield plot^{-1} (12.47 kg) was found from the treatment combination of M_0G_0 which was statistically similar to the treatment combination of M_2G_0.

Table 8. Yield parameters of cabbage as influenced by GA_3 and mulching

Treatments	Yield parameters					
	Fresh weight plant^{-1} (g)	Gross yield plot^{-1} (kg)	Gross yield ha^{-1} (t)	Marketable yield plant^{-1} (g)	Marketable yield plot^{-1} (kg)	Marketable yield ha^{-1} (t)
M_0G_0	1215.00 j	14.57 f	40.49 f	1039. 00 j	12.47 h	34.63 h
M_0G_1	1332.00 h	15.99 e	44.40 e	1171. 00 g	14.05 f	39.03 f
M_0G_2	1583.00 b	18.99 b	52.76 b	1357.00 c	16.28 bc	45.22 bc
M_0G_3	1405.00 f	16.86 d	46.83 cd	1264.00 e	15.17 de	42.15 de
M_1G_0	1240.00 i	14.88 f	41.33 f	1105.00 h	13.26 g	36.84 g
M_1G_1	1549.00 c	18.58 b	51.62 b	1346.00 c	16.16 bc	44.87 bc
M_1G_2	1673. 00a	20.07 a	55.76 a	1423.00 a	17.07 a	47.43 a
M_1G_3	1431.00 e	17.18 cd	47.71 cd	1290.00 d	15.48 de	42.99 de
M_2G_0	1226.00 ij	14.71 f	40.87 f	1080.00 i	12.96 gh	36.01 gh
M_2G_1	1386.00 g	16.63 d	46.19 de	1237.00 f	14.85 e	41.24 e
M_2G_2	1657.00 a	19.89 a	55.25 a	1381.00 b	16.58 ab	46.04 ab
M_2G_3	1462.00 d	17.55 c	48.74 c	1306.00 d	15.68 cd	43.55 cd
$LSD_{0.05}$	17.86	0.6199	1.907	17.05	0.6245	1.742
CV(%)	7.09	7.08	7.09	9.47	9.46	9.47

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

4.3.6 Marketable yield ha^{-1} (t)

Significant variation was recorded on marketable yield ha^{-1} of cabbage as affected by different mulching treatment (Fig. 5 and Appendix X). The highest marketable yield ha^{-1} (43.03 t ha^{-1}) was found from the treatment M_1 (polythene mulch) which was significantly different from other treatments followed by M_2 (straw mulch) whereas the lowest marketable yield ha^{-1} (40.26 t ha^{-1}) was recorded from the treatment M_0 (control condition). The result obtained from the present experiment was similar with the findings of Gupta and Gupta, (1987) and Farjana and Islam (2019).

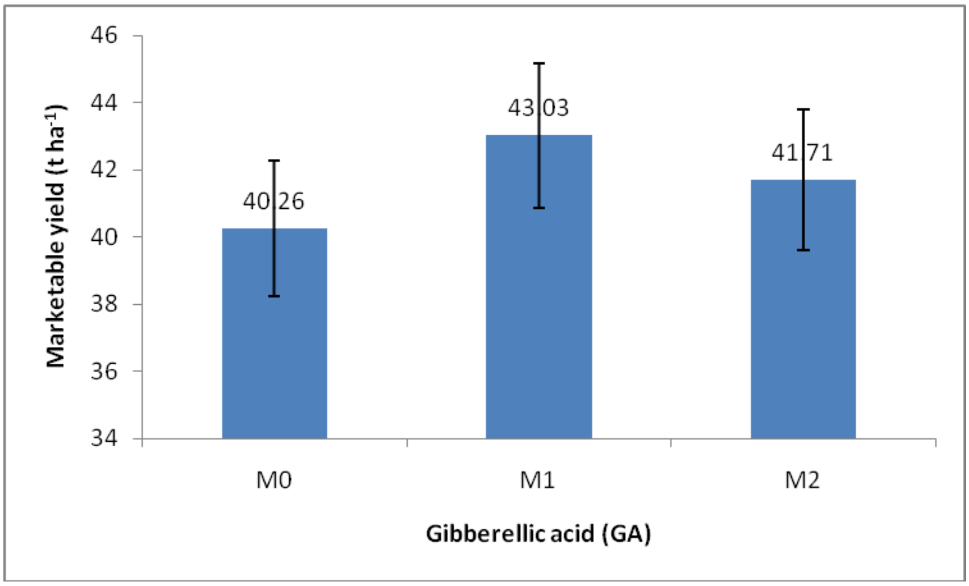

Fig. 5. Marketable yield ha^{-1} of cabbage as influenced by mulching

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch

Statistically significant difference among the treatment was found on marketable yield ha^{-1} of cabbage as influenced by different levels of gibberellic acid (Fig. 6 and Appendix X). The highest marketable yield ha^{-1} (46.23 t ha^{-1}) was obtained from the treatment G_2 (100 ppm GA_3) which was significantly different from other treatments followed by G_1 (80 ppm GA_3) and G_3 (120 ppm GA_3) whereas the lowest marketable yield ha^{-1} (35.82 t ha^{-1}) was achieved from the control treatment G_0 (0 ppm GA_3). The result on cabbage yield obtained from the present findings was similar with the findings of Chaurasiy *et al.* (2014), Roy and Nasiruddin (2011), Roy *et al.* (2010) and Lendve *et al.* (2010).

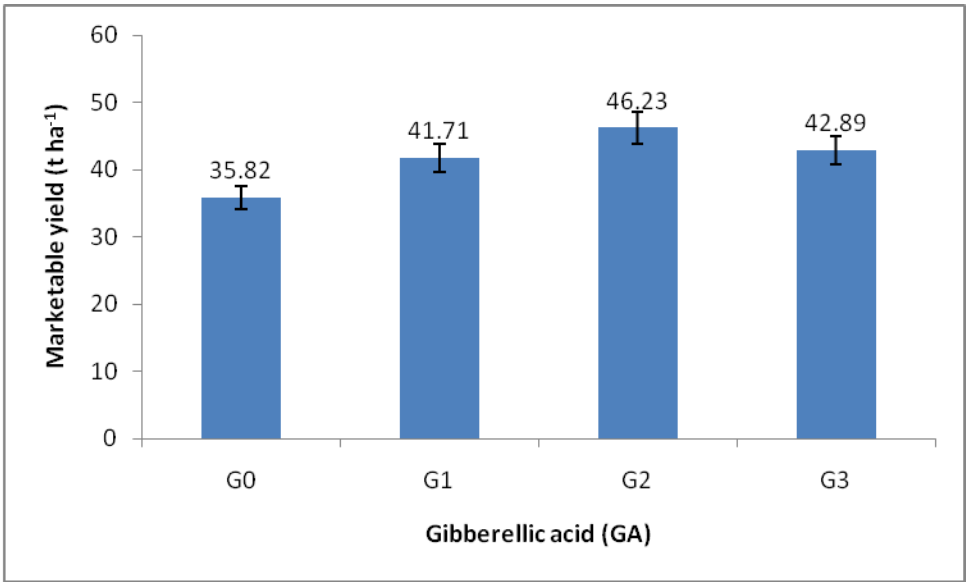

Fig. 6. Marketable yield ha^{-1} of cabbage as influenced by mulching

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

Combined effect of different levels of mulching and gibberellic acid showed significant variation on marketable yield ha^{-1} of cabbage (Table 8 and Appendix X). Results showed that the highest marketable yield ha^{-1} (47.43 t ha^{-1}) was recorded from the treatment combination of M_1G_2 which was statistically similar to the treatment combination of M_2G_2. The lowest marketable yield ha^{-1} (34.63 t ha^{-1}) was found from the treatment combination of M_0G_0 which was statistically similar to the treatment combination of M_2G_0.

4.4 Economic analysis

All the material and non-material input cost like land preparation, cabbage seed cost, manure and fertilizer cost, mulching cost, GA_3 purchase and application cost, irrigation and manpower required for all the operation, interest on fixed capital of land (Leased land by loan basis) and miscellaneous cost were considered for calculating the total cost of production from planting seed to harvesting of cabbage were recorded for unit plot and converted into cost per hectare (Table 9 and Appendix XI). Price of cabbage was considered at market rate @ Tk. 12 kg^{-1}. The economic analysis is presented under the following headlines:

4.4.1 Total cost of production

Results showed that the highest cost of production (Tk. 186781.00) was found from the treatment combination of M_1G_3 followed by the treatment combination of M_1G_2 (Table 9). On the other hand, the lowest cost of production was found from the treatment combination of M_0G_0 (Tk. 174769.00) (Table 9).

4.4.1 Gross income

The combination of different mulching and GA_3 levels showed different gross return (Table 9). Gross income was calculated on the basis of sale of cabbage. The highest gross return (Tk 569160.00) was obtained from M_1G_2 (mulching with polythene + 100 ppm GA_3) treatment combination and lowest gross return (Tk 415560.00) obtained from the treatment combination of M_0G_0 (No mulching + 0 ppm GA_3).

4.4.2 Net return

Treatment combinations of different mulching and GA_3 levels showed net returns variation (Table 9). The highest net return (Tk 383471.00) was obtained from the treatment combination of M_1G_2 (mulching with polythene + 100 ppm GA_3) followed by the treatment combination of M_2G_2 which showed second highest net return (Tk 370067.00) compared to other treatment combinations. The lowest net return (Tk 240791.00) obtained from the treatment combination of M_0G_0 (No mulching + 0 ppm GA_3) which was nearest to the treatment combination of M_2G_0.

Table 9. Economic analysis of cabbage production as influenced by mulching and GA_3

Treatments	Yield (t ha^{-1})	Total cost of production (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
M_0G_0	34.63	174769	415560	240791	2.38
M_0G_1	39.03	179137	468360	289223	2.61
M_0G_2	45.22	180229	542640	362411	3.01
M_0G_3	42.15	181321	505800	324479	2.79
M_1G_0	36.84	180229	442080	261851	2.45
M_1G_1	44.87	184597	538440	353843	2.92
M_1G_2	47.43	185689	569160	383471	3.37
M_1G_3	42.99	186781	515880	329099	2.76
M_2G_0	36.01	176953	432120	255167	2.44
M_2G_1	41.24	181321	494880	313559	2.73
M_2G_2	46.04	182413	552480	370067	3.03
M_2G_3	43.55	183505	522600	339095	2.85

M_0 = Control condition, M_1 = Polythene mulch, M_2 = Straw mulch
G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

4.4.3 Benefit cost ratio (BCR)

Among different treatment combinations of mulching and GA_3 levels, variation on BCR was observed among the treatment combinations (Table 9). The Benefit cost ratio (BCR) was highest (3.37) from the treatment combination of M_1G_2 (mulching with polythene + 100 ppm GA_3) followed by M_2G_2 and M_0G_2 (3.03 and 3.01, respectively) those were also promising compared to other treatment combinations. The lowest BCR (2.38) was obtained from the treatment combination of M_0G_0 (No mulching + 0 ppm GA_3). From economic point of view, it was noticeable from the above results, the treatment combination of M_1G_2 (mulching with polythene + 100 ppm GA_3) was more profitable than rest of the treatment combinations.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 to find out the effect of different mulch materials and GA_3 on growth and yield of cabbage during the period from October 2018 to March 2019. Cabbage seeds of Atlas 70 were used as planting materials. The experiment consisted of two factors: Factor A: three mulching practices as M_1 = Mulching with saw dust, M_2 = Mulching with polythene and M_3 = Mulching with straw and Factor B: four levels GA_3 application as G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3 and G_3 = 120 ppm GA_3. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield contributing parameters and yield parameters were recorded and statistically analyzed using MSTAT-C computer package program. Different mulching and GA_3 treatments and also their combinations showed significant influence of different growth, yield contributing parameters and yield of cabbage.

Different mulching treatment showed significant variation on growth and yield parameters of cabbage. Regarding growth parameters, the highest plant height (24.06, 35.69 and 45.87 cm at 30, 50 DAT and at harvest, respectively), number of loose leaves plant^{-1} (9.30, 12.72 and 17.99 at 30, 50 DAT and at harvest, respectively), leaf length (23.20, 28.57 and 31.00 cm at 30, 50 DAT and at harvest, respectively), leaf breadth (14.93, 18.24 and 19.43 cm at 30, 50 DAT and at harvest, respectively) and plant spread (19.08, 43.75 and 54.40 cm at 30, 50 DAT and at harvest, respectively) were recorded from the treatment M_1 (polythene mulch). Again, the lowest plant height (23.03, 33.17 and 42.63 cm at 30, 50 DAT and at harvest, respectively), number of loose leaves plant^{-1} (8.58, 11.72 and 16.87 at 30, 50 DAT and at harvest, respectively), leaf length (22.50, 27.98 and 29.70 cm at 30, 50 DAT and at harvest, respectively), leaf breadth (14.06, 17.02 and 18.50 cm at 30, 50 DAT and at harvest, respectively) and plant spread (17.40, 40.50 and 51.80 cm at 30, 50 DAT and at harvest, respectively) were found from the treatment M_0 (control condition). Considering yield contributing parameters, the highest % dry matter (11.28%), head diameter (12.25 cm), thickness of head (13.40 cm), stem length at harvest (3.92 cm) and % dry matter of stem (8.48%) were found from the treatment M_1 (polythene mulch) whereas regarding yield parameters, the highest fresh weight plant^{-1} (1473.00 g), gross yield plot^{-1} (17.68 kg), gross yield ha^{-1} (49.10 t ha^{-1}), marketable yield plant^{-1} (1291.00 g), marketable yield plot^{-1} (15.49 kg) and marketable yield ha^{-1} (43.03 t) were also recorded from the treatment M_1 (polythene mulch). Similarly, the lowest % dry matter (10.53%), head diameter (11.55 cm), plant (12.69 cm), plant at harvest (3.58 cm), p% dry matter of stem lant (8.07%), fresh weight plant^{-1} (1384.00 g), gross yield plot^{-1} (16.60 kg), gross yield ha^{-1} (46.12 t ha^{-1}), marketable yield plant^{-1} (01208.000 g), marketable yield plot^{-1} (14.49 kg) and marketable yield ha^{-1} (40.26 t ha^{-1}) were recorded from the treatment M_0 (control condition).

Different levels of GA_3 application showed significant influence on growth and yield parameters of cabbage. Regarding growth parameters, the highest plant height (23.92, 36.03 and 49.03 cm at 30, 50 DAT and at harvest, respectively) and leaf length (24.10, 29.84 and 33.04 cm at 30, 50 DAT and at harvest, respectively) were observed from the treatment G_3 (120 ppm GA_3) whereas the highest number of loose leaves plant^{-1} (10.41, 14.40 and 19.80 at 30, 50 DAT and at harvest, respectively), leaf breadth (16.51, 21.18 and 23.20 cm at 30, 50 DAT and at harvest, respectively) and plant spread (22.38, 47.40 and 57.71 cm at 30, 50 DAT and at harvest, respectively) were recorded from the treatment G_2 (100 ppm GA_3). Accordingly, the lowest plant height (20.54, 28.26 and 40.11 cm at 30, 50 DAT and at harvest, respectively), number of loose leaves plant^{-1} (7.75, 9.81 and 15.04 at 30, 50 DAT and at harvest, respectively), leaf length (21.49, 25.80 and 27.66 cm at 30, 50 DAT and at harvest, respectively), leaf breadth (12.17, 14.81 and 16.13 cm at 30, 50 DAT and at harvest, respectively) and plant spread (13.65, 34.07 and 46.86 cm at 30, 50 DAT and at harvest, respectively) were obtained from the control treatment G_0 (0 ppm GA_3). In terms of yield and yield contributing parameters, the highest % dry matter (12.14%), head diameter (13.35 cm), thickness of head (14.39 cm), stem length at harvest (3.45 cm), % dry matter of stem (8.99%), fresh weight plant^{-1} (1638.00 g), gross yield plot^{-1} (19.65 kg), gross yield ha^{-1} (54.59 t ha^{-1}), marketable yield plant^{-1} (1387.00 g), marketable yield plot^{-1} (16.64 kg) and marketable yield ha^{-1} (46.23 t ha^{-1}) were found from the treatment G_2 (100 ppm GA_3). Likewise, the lowest % dry matter (9.37%), head diameter (10.10 cm), thickness of head (11.51 cm), stem length at harvest (3.16 cm), % dry matter of stem (7.37%), fresh weight plant^{-1} (1227.00 g), gross yield plot^{-1} (14.72 kg), gross yield ha^{-1} (40.89 t ha^{-1}), marketable yield plant^{-1} (1075.00 g), marketable yield plot^{-1} (12.90 kg) and marketable yield ha^{-1} (35.82 t ha^{-1}) were found from the control treatment G_0 (0 ppm GA_3).

Different treatment combination of mulching and GA_3 also showed significant influence on different growth and yield parameters of cabbage. In terms of growth parameters, the highest plant height (24.47, 37.52 and 50.53 cm at 30, 50 DAT and at harvest, respectively) and leaf length (24.57, 30.44 and 33.72 cm at 30, 50 DAT and at harvest, respectively) were observed from the treatment combination of M_1G_3 but the highest number of loose leaves plant^{-1} (10.64, 14.88 and 20.40 at 30, 50 DAT and at harvest, respectively), leaf breadth (16.78, 21.48 and 23.62 cm at 30, 50 DAT and at harvest, respectively) and plant spread (23.52, 48.64 and 59.66 cm at 30, 50 DAT and at harvest, respectively) were observed from the treatment combination of M_1G_2. Conversely, the lowest plant height (20.27, 27.20 and 38.39 cm at 30, 50 DAT and at harvest, respectively), number of loose leaves plant^{-1} (7.64, 9.42 and 14.80 at 30, 50 DAT and at harvest, respectively), leaf length (21.32, 25.62 and 27.47 cm at 30, 50 DAT and at harvest, respectively), leaf breadth (11.92, 14.64 and 15.94 cm at 30, 50 DAT and at harvest, respectively) and plant spread (13.36, 33.61 and 46.21 cm at 30, 50 DAT and at harvest, respectively) were found from the treatment combination of M_0G_0. In case of yield and yield contributing parameters, the highest % dry matter (12.33%), head diameter (13.52 cm), thickness of head (14.62 cm), stem length at harvest (4.64 cm), % dry matter of stem (9.14%), fresh weight plant^{-1} (1673.00 g), gross yield plot^{-1} (20.07 kg), gross yield ha^{-1} (55.76 t ha^{-1}), marketable yield plant^{-1} (1423.00 g), marketable yield plot^{-1} (17.07 kg) and marketable yield ha^{-1} (47.43 t ha^{-1}) were recorded from the treatment combination of M_1G_2. On the other hand, the lowest % dry matter (9.12%), head diameter (9.92 cm), thickness of head (11.33 cm), stem length at harvest (3.07 cm), % dry matter of stem (7.26%), fresh weight plant^{-1} (1215.00 g), gross yield plot^{-1} (14.57 kg), gross yield ha^{-1} (40.49 t ha^{-1}), marketable yield plant^{-1} (1039.00 g), marketable yield plot^{-1} (12.47 kg) and marketable yield ha^{-1} (34.63 t ha^{-1}) was found from the treatment combination of M_0G_0.

Regarding economic analysis, the highest gross return (Tk 569160.00), net return (Tk 383471.00) and Benefit cost ratio (BCR) (3.37) were also recorded from the treatment combination of M_1G_2 whereas the lowest gross return (Tk 415560.00), net return (Tk 240791.00) and BCR (2.38) were also obtained from the treatment combination of M_0G_0 .

Conclusion

From the above results, it can be concluded that among the different treatment combinations of mulching and GA_3, mulching with polythene + 100 ppm GA_3 (M_1G_2) combination had best significant positive effect on growth and yield of cabbage and resulted highest marketable cabbage yield ha^{-1} (47.43 t ha^{-1}) compared to all other treatment combinations.

Recommendation

Considering the situation of the present study, further studies in the following areas may be suggested:

1. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Other mulching treatments may be used in future study.
3. Another plant growth regulators and/or GA_3 with different concentrations need to be considered before final recommendation.

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APPENDICES

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

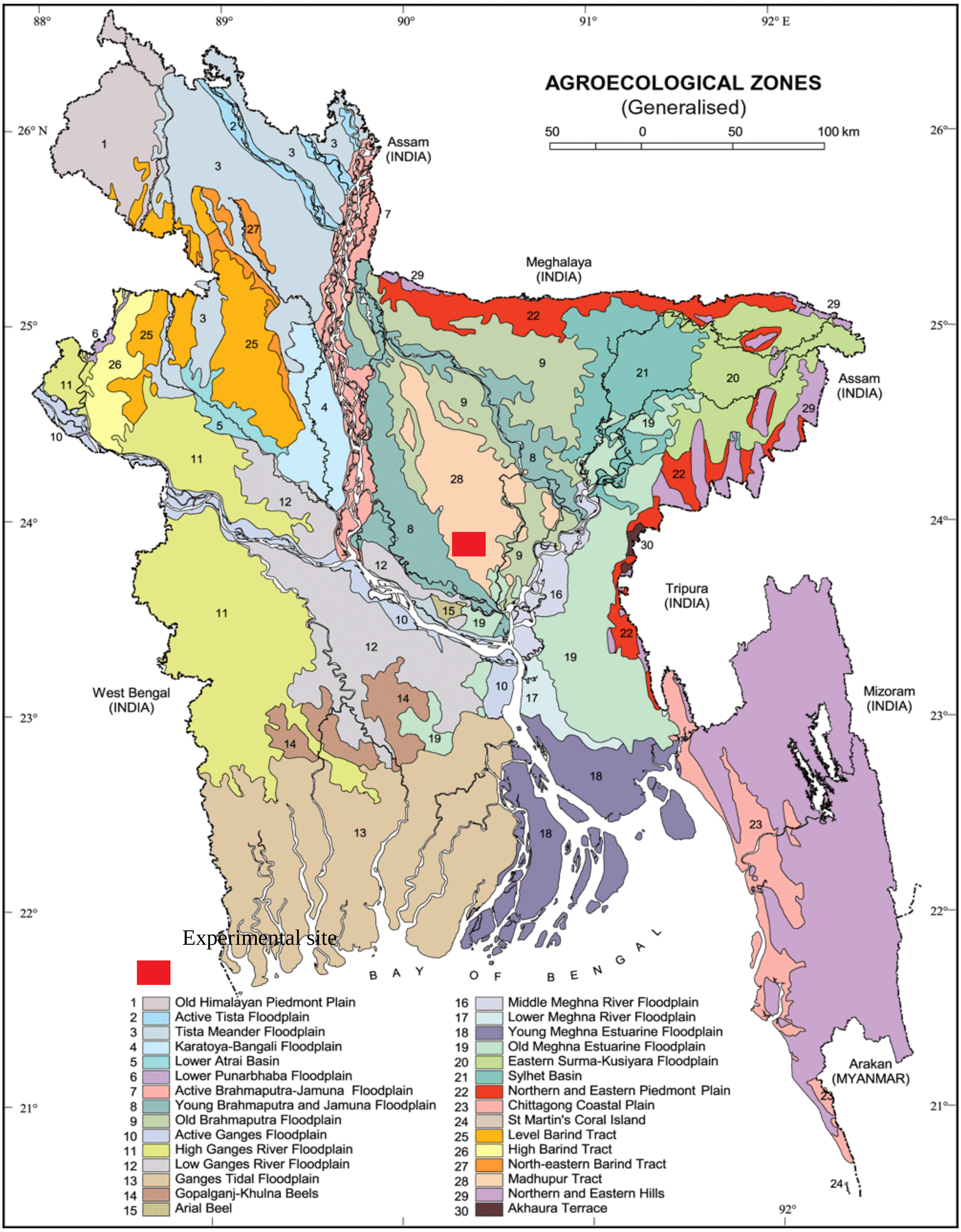

Fig. 7. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from September 2019 to December 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	September	30.8	21.80	26.30	71.50	78.52
2019	October	30.42	16.24	23.33	68.48	52.60
2019	November	28.60	8.52	18.56	56.75	14.40
2019	December	25.50	6.70	16.10	54.80	0.0

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

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

A. Morphological characteristics of the experimental field

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

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Mean square of plant height of cabbage as influenced by GA_3 and mulching

Sources of variation	Degrees of freedom	Mean square of plant height		
		30 DAT	50 DAT	At harvest
Replication	2	0.871	1.732	1.0329
Factor A	2	NS	32.03*	61.213*
Factor B	3	28.08*	172.03*	78.052*
AB	6	0.505**	8.032*	9.333*
Error	22	0.092	0.515	0.316

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Mean square of leaf number $plant^{-1}$ of cabbage as influenced by GA_3 and mulching

Sources of variation	Degrees of freedom	Mean square of number of loose leaves $plant^{-1}$		
		30 DAT	50 DAT	At harvest
Replication	2	7.802	0.034	0.178
Factor A	2	NS	3.068*	3.775*
Factor B	3	11.02*	31.87*	34.19*
AB	6	1.682**	2.111**	2.777*
Error	22	4.586	0.306	0.408

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Mean square of leaf length of cabbage as influenced by GA_3 and mulching

Sources of variation	Degrees of freedom	Mean square of leaf length (cm)		
		30 DAT	50 DAT	At harvest
Replication	2	3.296	0.183	0.316
Factor A	2	NS	NS	5.084*
Factor B	3	11.75*	28.13*	50.58*
AB	6	0.071**	2.204*	3.646*
Error	22	3.213	0.532	0.526

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Mean square of leaf breadth of cabbage as influenced by GA_3 and mulching

Sources of variation	Degrees of freedom	Mean square of leaf breadth (cm)		
		30 DAT	50 DAT	At harvest
Replication	2	0.176	0.006	0.014
Factor A	2	NS	4.489*	2.609*
Factor B	3	28.76*	62.78*	81.06*
AB	6	1.629**	1.574**	3.654*
Error	22	0.314	0.369	0.305

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Mean square of plant spread of cabbage as influenced by GA_3 and mulching

Sources of variation	Degrees of freedom	Mean square of plant spread (cm)		
		30 DAT	50 DAT	At harvest
Replication	2	0.334	0.145	0.314
Factor A	2	20.59*	47.782*	31.910*
Factor B	3	162.87*	297.03*	200.05*
AB	6	4.848**	11.132*	7.391**
Error	22	0.773	0.749	0.945

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Mean square of yield contributing parameters of cabbage as influenced by GA_3 and mulching

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters				
		% dry matter of head	Head diameter (cm)	Thickness of head (cm)	Stem length at harvest (cm)	% dry matter of stem
Replication	2	0.404	0.093	0.088	0.042	0.162
Factor A	2	2.654**	2.003**	0.603**	NS	0.521**
Factor B	3	14.50*	22.27*	21.213*	4.401*	4.101*
AB	6	0.86**	0.555**	0.894**	0.125**	0.123**
Error	22	0.546	0.283	0.668	0.709	0.114

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Mean square of yield parameters of cabbage as influenced by GA_3 and mulching

Sources of variation	Degrees of freedom	Mean square of yield parameters					
		Fresh weight $plant^{-1}$ (g)	Gross yield $plot^{-1}$ (kg)	Gross yield ha^{-1} (t)	Marketable yield $plant^{-1}$ (g)	Marketable yield $plot^{-1}$ (kg)	Marketable yield ha^{-1} (t)
Replication	2	34.255	0.190	1.483	55.350	0.806	6.220
Factor A	2	2409.90*	3.473*	26.77*	2081.59*	2.997*	23.133*
Factor B	3	25341.6*	36.49*	281.5*	15248.3*	21.95*	169.42*
AB	6	795.749*	1.141*	8.844*	359.702*	0.516**	3.991**
Error	22	41.243	0.034	0.268	52.353	0.136	1.058

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XI: Cost of production of cabbage per hectare

A. Input cost (Tk. ha^{-1})

Treatments	Cost of land preparation and cultivation with labor	Cabbage seed cost	Insecticide cost (Tk./ha)	Irrigation	Cowdung	Fertilizer			Mulching cost	GA_3 application cost	Seed bed preparation and seed sowing cost	Transplanting cost with labor	Subtotal (A)
						Urea	TSP	MoP					
M_1G_0	25000	7000	15000	15000	15000	4900	6250	4800	10000	0	3000	16000	121950
M_1G_1	25000	7000	15000	15000	15000	4900	6250	4800	10000	4000	3000	16000	125950
M_1G_2	25000	7000	15000	15000	15000	4900	6250	4800	10000	5000	3000	16000	126950
M_1G_3	25000	7000	15000	15000	15000	4900	6250	4800	10000	6000	3000	16000	127950
M_2G_0	25000	7000	15000	15000	15000	4900	6250	4800	15000	0	3000	16000	126950
M_2G_1	25000	7000	15000	15000	15000	4900	6250	4800	15000	4000	3000	16000	130950
M_2G_2	25000	7000	15000	15000	15000	4900	6250	4800	15000	5000	3000	16000	131950
M_2G_3	25000	7000	15000	15000	15000	4900	6250	4800	15000	6000	3000	16000	132950
M_3G_0	25000	7000	15000	15000	15000	4900	6250	4800	12000	0	3000	16000	123950
M_3G_1	25000	7000	15000	15000	15000	4900	6250	4800	12000	4000	3000	16000	127950
M_3G_2	25000	7000	15000	15000	15000	4900	6250	4800	12000	5000	3000	16000	128950
M_3G_3	25000	7000	15000	15000	15000	4900	6250	4800	12000	6000	3000	16000	129950

M_1 = Saw dust, M_2 = Polythene, M_3 = Straw

G_0 = Control (0 ppm GA_3), G_1 = 80 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 120 ppm GA_3

B. Overhead cost (Tk. ha^{-1}), Cost of production (Tk. ha^{-1}), Gross return (Tk. ha^{-1}), Net return (Tk. ha^{-1}) and BCR

Treatments	Overhead cost			Subtotal (B)	Subtotal (A)	Total cost of production (t ha^{-1})	Yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
	Cost of leased land for 6 months (8% of value of land 10,00,000/-)	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (8% of cost year^{-1})							
M_0G_0	40000	6097.5	6722	52819	121950	174769	34.63	415560	240791	2.38
M_0G_1	40000	6297.5	6890	53187	125950	179137	39.03	468360	289223	2.61
M_0G_2	40000	6347.5	6932	53279	126950	180229	45.22	542640	362411	3.01
M_0G_3	40000	6397.5	6974	53371	127950	181321	42.15	505800	324479	2.79
M_1G_0	40000	6347.5	6932	53279	126950	180229	36.84	442080	261851	2.45
M_1G_1	40000	6547.5	7100	53647	130950	184597	44.87	538440	353843	2.92
M_1G_2	40000	6597.5	7142	53739	131950	185689	47.43	569160	383471	3.37
M_1G_3	40000	6647.5	7184	53831	132950	186781	42.99	515880	329099	2.76
M_2G_0	40000	6197.5	6806	53003	123950	176953	36.01	432120	255167	2.44
M_2G_1	40000	6397.5	6974	53371	127950	181321	41.24	494880	313559	2.73
M_2G_2	40000	6447.5	7016	53463	128950	182413	46.04	552480	370067	3.03
M_2G_3	40000	6497.5	7058	53555	129950	183505	43.55	522600	339095	2.85

Selling cost of cabbage = 12 Tk^{-1}