INFLUENCE OF SEEDLING AGE AND NAA ON GROWTH AND YIELD OF CHINESE CABBAGE

KAMRUN NAHER

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2021

INFLUENCE OF SEEDLING AGE AND NAA ON GROWTH AND YIELD OF CHINESE CABBAGE

BY

KAMRUN NAHER

REG. NO.: 14-06251

A Thesis

Submitted to the Faculty of Agriculture

Sher-e-Bangla Agricultural University, Dhaka

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (MS)

IN HORTICULTURE

SEMESTER: JANUARY- JUNE, 2021

Approved by:

Prof. Dr. Md. Ismail Hossain
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

Prof. Dr. Mohammad Humayun Kabir
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Co-supervisor

Prof. Dr. Khaleda Khatun
Chairman
Examination Committee

DEPARTMENT OF HORTICULTURE

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **"Influence of Seedling Age and NAA on Growth and Yield of Chinese Cabbage** *(Brassica campestris* var. *pekinensis)"* submitted to Dept, of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE,** embodies the result of a piece of bona fide research work carried out by **KAMRUN NAHER,** Registration No. **14-06251** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2021

Dhaka, Bangladesh

Prof. Dr. Md. Ismail Hossain

Department of Horticulture

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Supervisor

Dedicated to

My

Beloved Parents

ACKNOWLEDGEMENTS

The author deems it a much privilege to express her enormous sense of gratitude to the Almighty ALLAH for His never ending blessings for the successful completion of the research work.

The author feels proud to express her deep sense of gratitude, sincere appreciation and immense indebtedness to her supervisor **Prof. Dr. Md. Ismail Hossain**, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his continuous guidance, cooperation, constructive criticism and helpful suggestions, valuable opinion in carrying out the research work and preparation of thisthesis, without his intense co-operation this work would not have been possible.

The author feels proud to express her deepest respect, sincere appreciation and immense indebtedness to her co-supervisor **Prof. Dr. Mohhamad Humayun Kabir** and all teachers, Department of Horticulture, Sher-e- Bangla Agricultural University, Dhaka, for his scholastic and continuous guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.

The author expresses her sincere respect to **Prof. Dr. Md Jahedur Rahman**, Chairman, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka for valuable suggestions and cooperation during the study period. The author also expresses her heartfelt thanks to all the teachers of the department of horticulture, Sher-e-Bangla Agricultural University, Dhaka for their valuable teaching, suggestions and encouragement during the period of the study.

The author expresses her sincere appreciation to her family, brother, sisters, relatives, friends and well-wishers for their inspiration, help and encouragement throughout the study.

The Author

INFLUENCE OF SEEDLING AGE AND NAA ON GROWTH AND YIELD OF CHINESE CABBAGE

Abstract

An experiment was conducted in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2019 to January 2020 to study the influence of seedling age and NAA on growth and yield of Chinese cabbage. The experiment consisted of two factors, such as Factor A: Seedling age (3 levels) as- A_1: 15 days old seedlings, A_2: 25 days old seedlings, A_3: 35 days old seedlings and Factor B: Different levels of NAA (4 levels) as N_0: 0 ppm (control), N_1: 40 ppm, N_2: 80 ppm and N_3: 120 ppm. The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield components and yield of Chinese cabbage were recorded. Statistically significant variation was recorded from all recorded characters due to the different levels of naphthalene acetic acid (NAA). Seedling age showed significant differences in all recorded characters. Seedling age and different levels of NAA influenced significantly on most of the parameters. Considerable highest values were recorded in head weight (1.69 kg) and gross yield (77.01 t/ha) from 25 days of seedling (A_2) and the lowest were recorded from A_3 and A_1. Considerable highest values were recorded in head weight (1.53 kg) and gross yield (75.72 t/ha) from 80 ppm (N_2) followed by 120 ppm (N_3) and 40 ppm (N_1) of NAA and the lowest value was recorded from control treatments. Interaction effect between different seedling age and NAA also showed significant differences and the considerable yield and yield contributing characters were recorded from the treatment combination A_2N_3, while the treatment combination A_3N_0 gave the lowest value. The highest gross return (Tk. 926,200), net return (Tk. 644,765) and benefit cost ratio (3.29) were obtained from the treatment combination A_2N_3 and the lowest (Tk. 727,980, 457,139 and 2.69 respectively) were from the treatment combination A_1N_0.

CONTENTS

CONTENTS (Contd')

CONTENTS (Contd')

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Chinese cabbage (*Brassica campestris* var. *pekinensis*) is a leafy vegetable. It is a herbaceous vegetable widely growing crop belonging to the family Brassicaceae and this is originated in China (Rashid, 1999). It is one of the most important crops in eastern Asia. It is also a familiar crop and widely distributed within Asia and has been introduced successfully into different parts of West Africa, Central America, America,Canada and Europe (Talekar and Selleck, 1982). This is also a kind of cabbage. In Japan, it ranks within major growing crops and the farmers in almost every homestead cultivate the crop. In Korea, it is the most important vegetable in terms of area and per capita consumption in every year.

Chinese cabbage is a short duration crop and it produced for its compact is a very useful food crop, an important cash crop, a palatable food item and rich source of calcium, crude fibre, and vitamins in human diet (Talekar and Griggs, 1981). Chinese cabbage is a valuable source of vitamin C and vitamin K, containing 44% and 72%, respectively. In addition to its usual purpose as an edible vegetable, Chinese cabbage has been used historically as a medicinal herb for a variety of purported health benefits. Chinese Cabbages are prepared many different ways for eating; they can be pickled, fermented or used as salad etc. The head is used as boiled vegetable, cooked in curries as well as dehydrated vegetable. Chinese cabbage head is an excellent source of many nutrients especially protein, carotene and mineral salts.

In Bangladesh Chinese cabbage is not so familiar and is being grown on a very small scale due to the lack of awareness. It is also limited scale producing crop due to lack of proper knowledge and accurate method of production technology. Now-a-days, an interest has been generated among the farmers for producing this crop extensively because of its rapid growth, higher yield and economic return. As a result, consumption, use, interest and attention towards Chinese cabbage are increasing day by day among the common people of our country (AVRDC, 1981).

The production package of Chinese cabbage is not well known to the farmers in Bangladesh. For getting higher production and quality yield in almost all crops, it is necessary to assure availability of essential nutrient components (Alam *et al.*, 1989).

Chinese cabbage thrives well in a fertile, clay loam soil because it requires considerable amount of nutrients proper size of seedling for quick growth in a short period of time (Islam and Haque, 1992).

Seedling age is an important occurrence for the production of different types of crops especially vegetables (Bose and Som, 1986). Young seedlings need very intensive care for adjustment with the new environmental condition, while aged seedlings confront more injury during uprooting and required more care for adjustment (Anon., 1992). So, it can assume that in both the situations yield from any crop may be hampered and yield can be decreased drastically. In other case, optimum aged seedlings are spontaneously adjusted within short period of time in the new environment. So, there were no or very little injury period of optimum aged transplanted seedlings.

Seedling age remarkably influences the vegetative development growth and mass, biochemical composition, output, plant growth after transplantation and hindrance to several critical conditions (Henare and Ravanloo, 2008). Older aged seedlings are more tolerant to stress and produce fruits earlier, while young transplants are less tolerant and produced fruits subsequently (Vavrina, 1998). Older aged seedlings after transplanting develop reproductive stage quicker than vegetative stage (Orzolek, 2004). When we transplanted the seedling in actual aged it ensured highest yield and also very good quality yield which maximize the total growth and yield (Thompson and Kelly, 1957). The effect of seedling age on yield is an issue often introduced by the growers to maximize production potential (Holcomb, 1994). Optimum aged seedlings of Chinese cabbage ensure early production as well as higher yield of crop which helps the farmers to get higher market price.

Application of plant growth regulator is one of the best ways for more vegetable production which is needed for the per capita per day intake of vegetables in Bangladesh. Now-a-days, plant growth regulators have been used to improve growth and ultimately yield. Growth regulators are organic compounds, small amounts of which are capable of modifying growth. Due to diversified use of productive land, it isneeded to increase food production and growth regulators may be a contributor in achieving the desired goal. Chinese cabbage was found to show a quick growth, increase number of leaves/plant and higher yield when treated with plant growth regulator especially GA_3 and NAA (Dhengle and Bhosale, 2008; Yadav *et al*., 2000; Kumar *et al*., 1996).

Naphthalene Acetic Acid (NAA) is a plant growth regulator which can manipulate the growth and yield of crops. It can also play a vital role in increasing physiological processes of Chinese cabbage. NAA is an essential growth regulator of many commercial horticultural products.

NAA is a synthetic hormone belongs to Auxins that play fundamental role in cell elongation, cell division, apical dominance, leaf senescence vascular tissue, differentiation, root initiation, leaf and fruit abscission, fruit setting ratio, prevent fruit dropping, promote flower sex ratio and flowering (El-Otmani *et al*., 2000; Williams and Taji, 1989; Davies, 1987). Foliar application of NAA has alsofound to improve plant height, number of leaves per plant, fruit size with subsequent increase in seed yield in different kind of crops (Abro *et al*., 2004; Lee and Kim, 1999). NAA influences plant growth, seed yield and seed quality of Chinese cabbage.

Considering the above situation, the present investigation has been undertaken with the following objectives:

i. To evaluate the influence of seedling age and to find out the actual age of seedling for economical production of Chinese cabbage.

ii. To find out the optimum level of NAA on growth and yield of Chinese cabbage.

iii. To determine the combined effect of seedling age and NAA for maximizing yield production of Chinese cabbage.

CHAPTER II

REVIEW OF LITERATURE

Chinese vegetable is a very nutritious valuable vegetable crop and gained attention of the researchers throughout the world to develop its suitable production technique among various research works investigations have been made in various parts of the world to determine the actual age of seedlings and different levels of Naphthalene acetic acid (NAA) for its successful cultivation. However, the combined effects of these production practices have not been defined clearly. In Bangladesh, there have not many studies on the influence of seedling age and different levels of Naphthalene acetic acid (NAA) on the growth and yield of Chinese cabbage. Relevant available information in this connection has been reviewed in this chapter under the following headings.

2.1 Literature on seedling age

Sarker *et al.* (2017) conducted an experiment in the Horticultural Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka -1207 during the periodfrom October, 2010 to March, 2011 to find out the effect of seedling age on the growth and yield of tomato. Three different seedling ages such as S_1= 20 days, S_2= 25 days and S_3= 30 days old seedling were used. The experiment was laid out in RCBD with three replications. Highest yield (87.57 t/ha) was obtained from (S_3= 30 days old seedling) while the lowest yield (59.21 t/ha) was obtained from (S_1= 20 daysold seedling).

Rajbir *et al.* (2005) conducted a field experiment to find out the effect of transplanting time (10 and 30 December and 20 January) on the growth and yield of tomato cultivar Rupali. Early planting (10 December) resulted in the highest vegetative growth, yield attributes, early and total fruit yield, whereas the lowest values for the parameters measured were lowest with 20 January transplanting. The highest net returns (Rs. 52,700/ha) was recorded with transplanting on 10 December.

Csizinszky and Schuster (2005) conducted a trial with residual effects of N (0, 50, 100 and 150 kg/ha) and organic manure (control, rice straw litter or farmyard manure (FYM)), supplied to rice seedlings transplanted on 15 and 30 June, on the yield, yield components. Results revealed that transplanting dates of had no significant residual effects on the yield, yield components and nutrient uptake. Seedling transplanted in 15 June gave the highest yield considered the other transplanted dated.

Zhao Rui and Chen (2004) conducted a trial to determine the effect of nutritive area on the growth of tomato seedlings grown in plug trays. They recommended to transplant middle-aged seedlings by evaluating the effects of seedling age and plug tray nursery area on yield.

Choi *et al.* (2002) reported that the effects of seedling containers and seedling ages on the growth and yield of tomato plants were examined to establish the criteria for appropriate seedling production methods in the summer season. The quality of seedlings was better when seedlings were grown in polyethylene pots than in 72-cell plug trays. Seedling quality was better with increasing the growth duration in black polyethylene pots, whereas growth durations did not affect seedling quality in plug trays. Fruits matured earlier with pot-grown seedlings for a long duration than with plug tray-grown seedlings for a short duration. The yields of tomato during the first two months were significantly higher in pot-nursed seedlings than the plug tray nursed seedlings. Also, the total yield of tomato during the four months period was highest in pot-nursed seedlings. In pot-grown seedlings, there were no yield differences between 35 days and 45 days old seedlings during the first two months of harvest, while the yields of 25 days old seedlings were much lower than the older seedlings (35 and 45 days old). Seedling ages had no effect on the cumulative yield for 3 months after the first harvest. With plug tray-grown transplants, the cumulative yield for the initial 3 months was highest in plants grown for 35 days in the nursery, followed by 25 days and 45 days. However, there were no significant differences among seedling ages in the total yield.

Aparajita (2002) reported that the age (3, 4, 5 and 6-week-old) of the seedlings of tomato cv. Pusa Ruby and augergines cv. Pusa Purple had significant effect on the yield contributing characters and yield of tomato.

In 2000-02 in Lithuania, an experiment was carried out by Staugaitis and Viskelis (2005) to the changes of the macro-element amounts and the influence of seedling age in the heads and plant residues of Chinese cabbage. Chinese cabbage hybrid Manoko F_1 was planted in the last ten days of July with different seedling age with optimum fertilizer doses. The soil texture was loamy sand on light loam. Findings revealed that the crop planted with 30 days old seedling produced 44 t/ha yields, total plant mass being 76.6 t/ha.

Cerne *et al.* (2000) carried out an experiment and reported that two soft leaved cultivars (Atrakcija and Meraviglia delle Quattro Stagioni) gave the same yield but 18 days earlier at transplanting than at direct sowing. These two cultivars had lower yield than the crisp-leaved lettuce cultivars Ljubljanska Ledenka and Great Lakes at transplanting and at direct sowing. At transplanting cv. Ljubljanska Ledenka and cv. Great Lakes gave the yield 19 days earlier in comparison with the direct sowing. Transplanted soft-leaved lettuce developed the heads 28 days earlier than directly sown crisp-leaved lettuce.

Okano *et al.* (2000) observed the effect of seedling age at planting on plant form and fruit productivity in single-truss tomato (*Lycopersicon esculentum* Mill.) grown hydroponically. Light interception and photosynthetic activity of the leaves were also examined in plants with different plant forms. Growth after planting was retarded in proportion to the duration of rising of seedlings. 25-days to 35-days (4 to 7 leaf stages) plug seedlings was considered to be most suitable for single-truss cultivation of tomato. Fruit yield was positively correlated with total leaf area. Frequent emergence of lateral shoots could not be inhibited by the use of over mature seedlings. Interception of solar radiation which was highest for the uppermost leaf decreased for the leaves toward the lower part of the plant. Radiation interception by individual leaves varied depending on the plant form, which influenced the rate of field photosynthesis. Only upper three leaves contributed to photosynthesis in a shorter plant, while many more leaves in a taller plant.

Sanjoy Saha (1999) studied the impact of seedling age (15 or 30 days old) and planting time (early: 16 November or late: 16 December) on the fruit yield performance of tomato (*Lycopersicon lycopersicum*) cultivars BT 18, BT 12, BT 10, BT 2 and MIXENT in upland rice (cv. Annada)- based cropping system. All cultivars performed well when planted early (with 15-days-old seedlings) and showed a declining trend in fruit yield and other yield- attributing characters when planted late with 30 days old seedlings. Among the tomato cultivars, remarkably good fruit yields of 60.7 and 47.0 t/ha were recorded from BT 18 during 1994-95 and 1995-96, respectively, when planted early with 15 days old seedlings. BT 12 gave fruit yields of 59.7 and 41.9 t/ha during 1994-95 and 1995-96, respectively. The economics of different tomato cultivars also showed the same trend. The gross return, net return and net return per rupee were highest in BT 18, followed by BT 12, respective of seedling age and planting time.

Lee and Kim (1999) observed the effects of seedling age (45, 60 or 75 days) and transplant (root ball, or up to cotyledon or first true leaf). Tomatoes plant height and stem diameter were not influenced by seedling age or planting depth. The cluster emerged node number was not affected by planting depth. The second cluster emerged node number was lower in 45-days-old seedlings compared with older seedlings. Average fruit weight was lowest in first cluster regardless of seedling age. The number of marketable fruits was not influenced by planting depth, but was highest in 60-days-old seedlings. The highest marketable yields (1699-1849 g/plant) were obtained from 60-days-old seedlings.

Tanaka *et al.* (1998) carried out an experiment to observe the relationship of the first fruit, the age of seedling where scions had been taken, and the node position of initial bearing to devise ways that would not delay harvesting time of first fruit thus, reducing deterioration of fruit quality of eggplant cultivated by direct planting in plug seedlings. When the first flower was removed, the plant grew very well during early stage. This shows that the first bearing influences early growth. There was a significant inverse correlation between seedling age where scions were taken and the node position of the first fruit. Plants grafted with scions taken from seedling of advanced age bore first fruit in low node position and maintained favorable growth at early stage. Having first fruit in the lower node position causes an earlier occurrence of first harvest, lengthens the bearing branches and more increases the number of bearing parts, all of which contributes to high total yield.

Chui *et al.* (1997) conducted a greenhouse and field experiment with three tomato cultivars to study the influence of seedling age (4, 6, 8 or 10 weeks) on growth and early yield of fresh market tomatoes. Seedlings more than 6 weeks old showed slower growth and recovery after transplanting (RAT) and took longer time to flower in all 3 cultivars. Although older seedlings (> 8 weeks) had restricted roots, they produced higher early yields than younger seedlings. Three tomato cultivars were grown using the plug system or traditionally from seedlings sown in the field. They were then planted when 2 to 8 weeks old. There were no differences in performance of seedlings from the 2 different nursery systems when seedlings were less than 4 weeks old at planting. After 4 weeks, the growth rate of the field sown seedlings was greater than those raised as plugs.

Rahman *et al.* (1994) reported that in experiments of tomato cv. Manik. seedling age at transplanting had a significant effect on the number of days until flowering commenced, the number of days until harvest, number of fruits/plant and yield. Plants grown from younger seedlings flowcnxl and were ready to harvest earlier than those grown from older seedlings. The numbers of fruit plant and average fruit weight were greatest when seedlings were 40 days old at transplanting.

Chowdhury *et al.* (1991) was conducted an experiment to evaluate the influence of age of seedlings (30, 40, 50 and 60 days) on growth and yield of brinjal. Age of seedlings significantly influenced the number of days to flower, plant height, foliage spread, fruit size, number of fruits per plant and yield. Although the yield was increased with increasing age of seedlings there was no statistical difference among 40, 50 and 60 days old seedlings but they out yielded the crop from 30 days old ones.

In Bangladesh, Rahman and Quasem (1986) carried out a trial to observe proper age of seedling on yield of tomato. The age of seedling did not show any significant difference for all yield and yield contributing characters studied except days to first flower, days to 50% flower and days to first fruit set where earliness was observed with the increased age of seedling. Yield increase of 8 tons per hectare was obtained from 40 days old seedling (64.53 t/ha) over 20 and 30 days of seedling.

Adelana (1976) reported that the earliest planting of tomato seedlings resulted in greater leaf area, higher yield and number of fruits per plant and greater average fruit weight than later planting. Souma *et al.* (1976) while investigating into the effect of the length of the seedling age on the growth, yield and quality of tomato reported that the seedlings transplanted 40 days after sowing grow best and that abnormal fruits were produced by the plants transplanted 60 and 70 days after sowing. Dayan *et al*. (1978) have indicated that delayed planting reduced overall yield.

On the other hand, while investigating into the effect of different methods and time of sowing on yield and quality of tomato found that the number of fruits per plant and mean yield per plant decreased with delay in sowing date. Sowing date and transplant age have tremendous effect on growth and yield of tomato (Ravikumar and Shanmugavelu, 1983).

2.2 Literature on NAA

Tapdiya *et al.* (2018) conducted an experiment to study the effect of growth regulators on quantitative characters of chilli (*Capsicum annuum* L.). The study revealed that the seed treatment and foliar application influenced on the yield attributing character of chilli over control. The result exhibited that the growth regulators namely NAA and GA_3 foliar spray during flower bud initiation stage was found to be beneficial for increasing the plant height, number of branches per plant and stem girth over seed treatments compared to control. With regards to yield contributing character i.e. fruit setting percentage, fruit length, fruit girth, average fruit weight, number of fruit per plant, number of seeds per fruit, seed weight per fruit, and fruit yield per plant showed increase in foliar spray of NAA 40 ppm than all other treatment including control.

Choudhary *et al.* (2018) conveyed a field experiment consisted of four levels of nitrogen (0, 30, 60 and 90 kg/ha) and five PGRs (control, NAA @ 50 ppm at 40 DAS, NAA @ 50 ppm at 40 and 60 DAS, thiourea @ 500 ppm at 40 DAS and thiourea @ 500 ppm at 40 and 60 DAS). The results revealed that application of PGRs significantly increased protein content and essential oil content in seed of ajwain over control, however all PGRs remained at par to each other, foliar application of thiourea @ 500 ppm spray at 40 and 60 DAS significantly increased seed (1112 kg/ha), straw (3082 kg/ha) and biological yields (4195 kg/ha) over thiourea @ 500 ppm spray at 40 DAS, NAA @ 50 ppm spray at 40 DAS and control but remained at par with NAA @ 50 ppm spray at 40 and 60 DAS in yield attributes and yields.

Bhat and Singh (1998) reported that NAA had significant effect on growth yield and yield contributing characters of okra and different combinations of NAA and GABA significantly gave advanced fruiting by 3.33 days. They found that 100 seed weight of okra was increased significantly with the application of 150 ppm NAA.

Patel *et al.* (2016) conducted a field experiment on chilli cultivar "Kashi Anmol" at SHIATS, Allahabad, UP. They applied two methods of application of PGR one was soaking seed and another foliar application. They found seed yield per plant (8.30g), seed yield per fruit (0.35g) and fresh weight of fruits per plant (39g) with NAA @ 40 ppm. Foliar spray of 40 ppm NAA at bud initiation stage increase in seed yield and quality parameters.

Singh *et al.* (2015) carried out a trial on chilli variety "Pusa Jwala" with three treatments included farmers practice (T_1), NAA (T_2) and technology option (T_3) at KVK, Malda, West Bengal, under rain fed medium to upland sandy loam soil situation in rabi season. They sprayed NAA at the opening of first flower to last phase of flowering at 15 days interval. The result showed NAA reducing flower drop and increase in fruit set of chilli. Highest yield of chilli (14.37 q/ha) at NAA @ 50 ppm and followed by (12.32 q/ha) yield with NAA @ 20ppm.

Singh *et al.* (2014) studied on chilli variety G-4 at SHIATS, Allahabad, UP. They confined that the combined application of NAA @ 20 ppm, GA_3 @ 10 ppm and 2, 4-D @ 1 ppm significantly increased vegetative growth, yield and quality of chilli. Combined application had positive effect on plant growth, flowering and yield potential of plants.

Gedam *et al.* (1998) reported that bitter gourd (*Momordica charantia*) plants treated with 15 ppm, 25 ppm or 35 ppm GA_3 50 ppm, 100 ppm or 150 ppm NAA, 50 ppm, 100 ppm or 150 ppm ethephon 100 ppm, 200 ppm or 300 ppm maleic hydrazide, 2 ppm, 4 ppm or 6 ppm boron or with water (control). GA_3 at 35 ppm produced the earliest female flower and NAA at 50 ppm produced the earliest male flower. Fruit maturity was earliest in plants treated with 50 ppm NAA or 4 ppm boron. Fruit and seed yield were also highest in these treatments.

Moniruzzaman *et al.* (2014) conducted an experiment on brinjal having six PGR Viz.,GAs 30, 40, 50 ppm and NAA @ 20, 40, 60 ppm respectively and two varieties Viz., "BARI Begun-5" and "BARI Begun-10 during rabi season for determine suitable dose of PGR for brinjal production. The variety "BARI

Begun-5" was earlier to 100% flowering which took 44 days after transplanting which out yielded BARI Begun-10. NAA @ 40 ppm coupled with BARI Begun-5 gave the highest fruit yield 49.73 t/ha.

Thapa *et al.* (2013) studied the influence of NAA and GA_3 on quality attributing character of sprouting Broccoli variety "Italica plank" at BCKV, Mohanpur. They confirmed that NAA (30mg/l) + GA_3 (30mg/l) showed best result with respect to head diameter, plant height, spreading and yield. The plant growth regulator treatments significantly improved carotene, total sugar and total chlorophyll content, with highest increase have been recorded in case of T_1- GA_3 40 mg/l, whereas maximum ascorbic content has been estimated with T9- GA_3 20 mg/l+ NAA 20 mg/l. GA_3 (80 mg/l) treatment proved to be the most effective among all treatments and required minimum days for head initiation to head maturity.

Nkansha *et al.* (2012) conducted an experiment to study the effect of plant growth regulators on fruit set and yield on "Keitt" mango trees in order to study the effect of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) sprays at different concentrations on fruit retention, fruit quality and yield. Trees were sprayed at full bloom stage. All sprayed chemicals significantly increased fruit retention and tree yield. GA_3 (25 ppm) and NAA (25 ppm) gave the best results in terms of increasing fruit set, fruit retention, number of fruits per cluster and per plant, fruit weight and yield. No significant differences were observed between the quality of fruits harvested from treated and control trees. 25 ppm of GA_3 and 25 ppm NAA can be employed for spraying mango flowers at full bloom to increase mango fruit set, retention and yield of growers.

Olaiya *et al*. (2010) reported the effect of Indole-3-acetic acid (IAA), Indole-3-butyric acid (IBA) and Naphthalene acetic acid (NAA) at 60, 100 and 140 mg/L was evaluated on some biochemical indices of the nutritional quality of tomato (*Solanum lycopersicum*). The parameters evaluated were crude proteins, crude fat, crude fibre, ash, dry matter, titratable acidity, total carbohydrate, total soluble solids (oBrix), pH and oBrix/Acid ratio. The results showed that all the concentrations of IAA, IBA and NAA increased the levels of crude proteins, crude fat, crude fibre, ash, titratable acidity but decreased the total carbohydrate content. A decrease in dry matter content was evident in 60 mg/L of IAA, IBA, NAA and 100 mg/L of NAA. The pH of tomato pulp decreased in treatments involving 100 mg/L of IAA and 140 mg/L of IAA and NAA respectively. The total soluble solid content and oBrix/Acid ratio were significantly higher ($P < 0.05$) in the 100 mg/L NAA treatment. The results indicated that the bioregulators could enhance the basic tomato nutrients of importance in human diet.

Deb *et al*. (2009) found significant response of NAA (25 ppm) with respect to number of fruits/plant, fruit weight/plant, total soluble solid (TSS) and vitamin C and yield was obtained over the control. Adventitious root formation in tomato cuttings was totally suppressed with the application of IAA and IBA combination. They further observed the best root formation in tomato cuttings in 1.00mg NAA/L.

Iqbal *et al.* (2009) observed significant variation among various fruit quality parameters that is TSS, total sugar, acidity and ascorbic acid contents by the foliar application of NAA in guava.

Sridhar *et al.* (2009) conducted a trial on Bell Pepper at COA, Dharwad. They used three doses of NAA (50, 100 and 150 ppm) and Mepiquat chloride (500, 1000 and 1500 ppm) and observed the effect on yield, physiological and biochemical parameters of Bell Pepper variety “Tarihal”. They found that fruit yield was significantly high (159.89 g/plant) 45 DAT.

Iqbal *et al.* (2009) reported that the foliar spray with NAA at concentrations of 45 and 60 ppm when applied at marble and walnut stages of development in summer crop, significantly increased the fruit yield in guava.

Mehraj *et al.* (2015) stated the impact of GA_3 and NAA on Horticultural Traits of *Abelmoschus esculentus*. The experiment was carried out using BARI

Dherosh-1 as genetic materials and some growth regulators viz. G_0: Control (fresh water); G_1: GA_3 (Gibberellic acid) and G_2: NAA (Naphthalene acetic acid) @ 50 ppm. Tallest plant (89.0 cm), longest petiole (29.0 cm), number of leaves (49.0/plant), leaf area (29.7 cm), number of branches (5.5/plant), fresh weight (84.5 g/plant), dry weight (10.9 g/plant), number of pods 2 (33.4/plant), pod length (17.5 cm), pod diameter (1.7 cm) and yield (338.1 g/plant, 2.9 kg/plot and 16.4 t/ha) was found from G_1 which was statistically identical with G_2 while minimum from G_0. GA_3 and NAA have the potentiality to increase the yield of okra, but GA_3 was found to be most effective in the present study.

Vejenda and Smith (2008) conducted a field experiment to study the effect of chemicals and growth regulators on fruit retention, yield and quality of mango cv. Amrapali. Treatments comprised: NAA at either 25 or 50 ppm, 2, 4-D at either 10 or 20 ppm, $ZnSO_4$ at 0.50% or 0.75% KNO_3 at 0.50% or 0.75%, and a control (water spray). Two sprays were applied, one at pea stage and other at marble stage. The chemicals and growth regulators showed significant influence on the fruit retention and yield of Amrapali over the control. NAA at 50 ppm recorded maximum (9.85%) fruit retention per panicle followed by 2, 4-D at 10 ppm. Plants receiving NAA at 50 ppm produced the highest number of fruits per plant and yield (88/plant and 16.24 kg /plant) followed by 2,4-D at 10 ppm and NAA at 25 ppm.

Abu-Rayyan *et al.* (2004) recorded higher yield per plant of Camarosa strawberry with the application of NAA.

Jain Guo *et al.* (2004) observed the pre- harvest application of NAA at 40 mg per litre obtained maximum size of litchi fruits. Various concentration of 2, 4-D, GA_3 and NAA were applied during the last week of November, to check the impact of various treatments on preharvest fruit drop, yield and fruit quality. Exogenous application of growth regulators significantly decreased pre harvest fruit drop percentage, leading to increase in total number of fruits per plant, fruit weight, juice percentage, total soluble solids, acidity, vitamin-C, reducing sugars and non-reducing sugars % age while no effect was observed on fruit size. Auxin (2, 4-D and NAA) performed better compared to gibberellins.

In a field experiment carried out by Wang and Li (2004), the effects of different growth regulators and substrates were studied. The regulators used were NAA, ABT [amino benzotriazole] root-promoting powder, and IBA applied at 1000, 1500, and 2000 mg/litre. Water was used as control. The survival rate for cuttings and plant quality improved significantly with 1000 and 1500 mg NAA/litre. ABT treatment at 1500 mg/litre did not improve survival rate, but improved plant quality. Plant height, number of leaves, leaf area, root length, fresh leaf weight, fresh root weight, dry leaf weight, and dry root weight increased by 47.46, 35.42, 193.92, 235.79, 89.90, 40.51, 40.79, and 53.44%, respectively, as compared with the control.

Rai *et al.* (1998) studied with hormones on yield and quality of okra. Seeds were treated and foliar application with 100 ppm GABA, 0.25 ppm potassium dihydrozen orthophosphate and 10 ppm NAA was done at Mohanpur, West Bengal, India in the rainy season of 1994. They observed that the length of fruit was generally improved by foliar application of NAA and fibre quality was generally improved by foliar application of 10 ppm NAA. Path analysis for fibre fineness revealed that cell length/width ratio had a high direct effect. Cell breadth and fibre length showed very high direct effects on tenacity, while fibre fineness and tenacity were negatively correlated.

Kar *et al.* (2003) conducted an experiment on the effect of variety and growth regulators on growth and yield of cabbage (*Brassica oleracea* var. *capitata*) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh, Bangladesh during October, 2002-March, 2003. The highest gross and marketable yield of cabbage were obtained from the plants sprayed with 50 ppm NAA (Naphthalene Acetic Acid).

Yadav *et al.* (2000) conveyed a trial on 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.

Vijoy and Kumar (2000) observed that 30 days old Cauliflower (cv. Pant Subhra) seedling were transplanted into experimental plots and treated with 50 or 100 ppm GA_3, 5 or 10 ppm IBA, or 100 or 200 ppm NAA at 15 and 30 days of growth. The results clearly revealed that GA_3 produced the tallest plants, the largest curds and the highest curd yields.

Das and Rabhal (1999) conducted an experiment in a greenhouse on cucumber cultivars Chinese green, Pusa Sanyog and poinsett, NAA was applied at 30 ppm or 100 ppm kinetin at 10 ppm or 50 ppm and Ethrel at 250 ppm or 500 ppm at the 4 to 5 leaf stage and at flower bud appearance. NAA application produced the largest fruit with the highest flesh, placenta ratios. TSS and ascorbic acid content were highest when Ethrel was applied.

Sayed *et al*. (1997) conveyed an experiment with three growth regulators such as gibberellic acid (GA_3), Planofix (NAA) and cultar (paclobutrazol) on growth, yield and yield contributing characters of okra. Each growth regulator was applied to the foliage at the rate of 50, 100, 150 and 200 ppm on okra where NAA was found most effective in increasing the branches plant^{-1}. They found that 150 ppm NAA reduced the number of days to first picking whereas 200 ppm cultar delayed it. They observed that application of planofix (NAA) to okra at 20 DAS increased the pod length and 150 ppm NAA showed the greatest number of seeds pod^{-1}.

Laskshmamma and Rao (1996) reported that application of 0, 5, 10 or 20 ppm NAA on black gram at 50% flowering stage increased plant height.

Dharmender *et al.* (1996) conducted an experiment with growth regulators and found that GA_3 and/or NAA (both at 25, 50 or 75 ppm). On the yield of cabbages (ev. Pride of India) was investigated in the field at Jobner, Rajasthan, India. Yield was observed following treatment with 50 ppm GA_3 followed by 50 ppm NAA. Combinations and higher concentration of plant growth regulators proved less effective and were uneconomic in comparison to the control.

Chatterjee and Sukul (1995) conducted a trial with plant growth regulators for controlling the root-knot incidence in okra plants. Three plant growth regulators viz gibberellic acid, a-naphthalene acetic acid and boric acid were used as foliar sprays on okra plants against *Meloidogyne incognita* infestations in okra plants, in a pot culture experiment. The growth regulator in general, particularly the NAA was effective in reducing the disease intensity and inducing higher growth rates in the plant.

Harrington *et al.* (1996) reported leaf area and stem elongation was 20-30% more with the application of growth hormones applied in okra plant.

Islam *et al.* (1993) was made in investigation to determine the effective concentration of NAA and GA_3 for promoting growth, yield and ascorbic acid content of cabbage. They used 12.5, 25, 50, 100 ppm both the NAA and GA_3 and applied at three different methods i.e. seedling soaked for 12 hours, spraying at 15 and 30 days after transplanting. They found that ascorbic acid content increased up to 50 ppm when sprayed twice with both the growth regulators, 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.

Pandey and Sinha (1987) reported that photosynthetic area of the plant increased when treated with gibberellic acid and naphthalene acetic acid.

Patil *et al.* (1987) conducted an experiment in a field trial with the cabbage cultivar Pride of India by applying GA_3 and NAA each at 25, 50, 75 and 100 ppm one month after transplanting. Both the GA_3 and NAA increased the plant height significantly. The maximum plant height and head diameter and head weight were noticed with GA_3 at 50 ppm followed by NAA at 50 ppm. Significant number of outer and inner leaves was noticed with both GA_3 and NAA. Head formation and head maturity was 13 and 12 days earlier with 50 ppm GA_3. Maximum number of leaves and maximum yield (23.83 t/ha) were obtained with 50 ppm GA_3.

Muthoo *et al.* (1987) reported that foliar application of different concentrations of GA_3, NAA and Mo (in various combination or separately) increased the average fresh weight and dry weight of leaves and curd and yield. Among individual application, GA_3 was the best for vegetative growth and Mo followed by NAA for curd growth and yield.

Abdalla *et al.* (1980) conducted an experiment with the cauliflower varieties and the plant were treated with different concentrations of IBA (5-40ppm), GA_3 (10-80ppm) or NAA (120-160ppm) 4 weeks after transplanting and twice more at fortnightly intervals. NAA at 160 ppm gave the height yield with regard to card diameter, weight and color. Similar results were obtained from plants treated with GA_3 at 80 ppm and NAA at 40 ppm.

CHAPTER III

MATERIALS AND METHOD

An experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the influence of seedling age and NAA on growth and yield of Chinese cabbage. This chapter includes materials and methods that were used in conducting the experiment. It consists of a short description of location of the experimental site, characteristics of soil, climate, materials used for the seedlings, treatment of the investigation, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, irrigation, harvesting, data collection procedure, economic and statistical analysis etc. The details regarding materials and methods of this experiment are presented below under the following headings –

3.1 Location of the experimental site

The experiment was conducted in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2019 to January 2020. The location of the experimental site was $23^{0}74^{/}$ N Latitude and $90^{0}35^{/}$ E Longitude with an elevation of 8.2 meter from the sea level (Anon., 1989).

3.2 Climate of the experimental site

The geographical situation of the experimental site was under the subtropical climate, characterized by three distinct seasons, the monsoon or rainy season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al.,* 1979). The total annual rainfall of the experimental site was 218 mm and average monthly maximum and minimum temperatures were 29.45°C and 13.86°C, respectively. Details of the metrological data of temperature (°C), relative humidity (%), rainfall during the period of the experiment was collected from the Bangladesh Meteorological Department (Climate Division) and presented in Appendix I.

3.3 Characteristics of soil

The soil of the experimental area was Red brown terrace soil and belongs to the Modhupur Tract (UNDP, 1988) under AEZ 28. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The experimental site was a medium high land and pH of the soil was 5.6. The characteristics of the soil under the experimental plot were analyzed in the SRDI, Soil testing Laboratory, Khamarbari, Dhaka and details of the soil characteristics are presented in Appendix II.

3.4 Experimental details

3.4.1 Planting materials

In this research work, the seeds of variety blues of hybrid Chinese cabbage of TAKII SEED were used collected from Kushtia Seed Store, Mirpur - 11, Dhaka - 1216.

3.4.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Seedling age (3 levels) as

i. A_1: Transplanting of 15 days old seedlings
ii. A_2: Transplanting of 25 days old seedlings
iii. A_3: Transplanting of 35 days old seedlings

Factor B: Levels of NAA (4 levels) as

i. N_0: 0 ppm (control)
ii. N_1: 40 ppm
iii. N_2: 80 ppm
iv. N_3: 120 ppm

There were 12 (3 × 4) treatments combination such as A_1N_0, A_1N_1, A_1N_2, A_1N_3, A_2N_0, A_2N_1, A_2N_2, A_2N_3, A_3N_0, A_3N_1, A_3N_2 and A_3N_3.

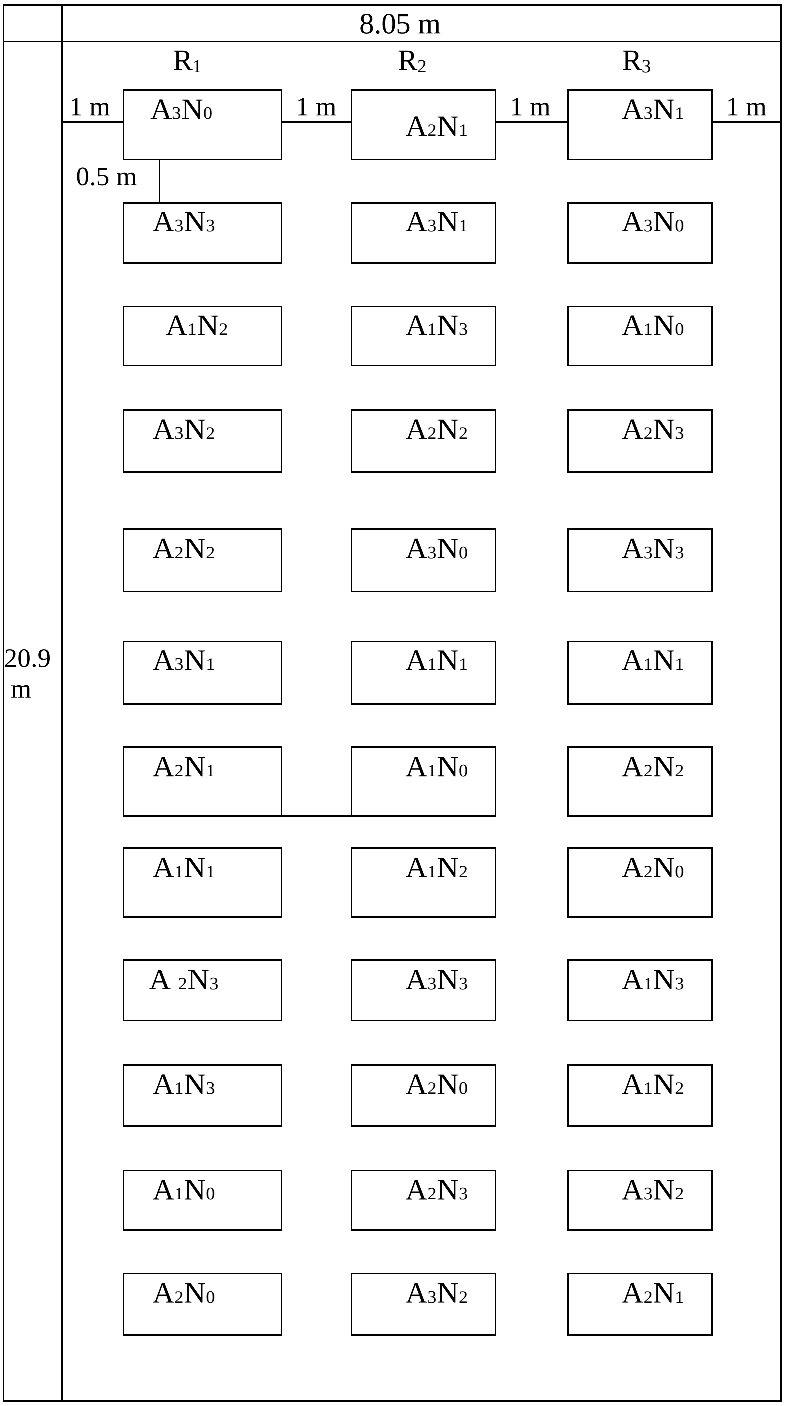
3.5 Raising of seedling

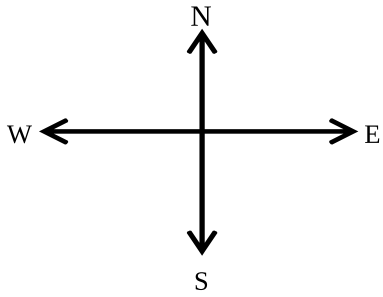
The seedlings were raised at Horticulture Farm, SAU, Dhaka with special care in a 3 m x 1 m seed bed. The soil of the seed bed was well ploughed with a spade and prepared to obtain good tilth to provide a favorable condition for the growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease cupravit fungicide was applied.

Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Ten grams of seeds were sown in each seedbed on October 15, 2019. After sowing, the seeds were covered with light soil. At the end of germination shading was given by white transparent polythene over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering and weeding were provided as and when necessary to provide seedlings with ideal condition for better growth.

3.6 Design and layout of the experiment

The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the treatment combinations in each plot of each block. Each block was divided into 12 plots where 12 treatment combinations were allotted at random. There were 36 units plots altogether in the experiment. The size of the plot was 1.35 m x 1.2 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively (Figure I)





Plot size: 1.35 m x 1.2 m

Spacing: 60 cm x 45 cm

Factor A: Seedling age (3 levels) as

i. A_1: 15 days of seedlings
ii. A_2: 25 days of seedlings
iii. A_2: 35 days of seedlings

Factor B: NAA (4 levels) as

i. N_0: 0 ppm (control)
ii. N_1: 40 ppm
iii. N_2: 80 ppm
iv. N_3: 120 ppm

Figure 1: Layout of the experiment

3.7 Preparation of the main field

The selected experimental plot was opened in the last week of October 2019 with a power tiller and was exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil for planting of Chinese cabbage seedlings. The experimental plot was partitioned into the unit plots in accordance with the experimental design. Recommended doses of well-rotten cowdung manure and chemical fertilizers were mixed with the soil of each unit plot. The soil was treated with fungicide cupravit against the fungal attack and furadan against the nematode attack.

3.8 Application of manure and fertilizers

Well decomposed cowdung as per treatment was applied at the time of final land preparation. The sources of fertilizers used for N, P, K, S, Zn and B were urea (300 kg/ha), TSP (200 kg/ha), MP (250 kg/ha), Gypsum (100 kg/ha) and zinc sulphate (30 kg/ha), borax (10 kg/ha) respectively. The entire amounts of TSP, MP, Gypsum and Zinc sulphate were also applied during the final land preparation. Only urea was applied in three equal installments at 10, 20, 30 DAT.

3.9 Application and preparation of NAA

The stock solution of 1000 ppm of NAA was made by mixing of 1 g of NAA with small amount of ethanol to dilute and then mixed in 1 litre of distilled water. Then as per requirement of 40 ppm, 80 ppm and 120 ppm solution of NAA, 40, 80 and 120 ml of stock solution were mixed with 1 litre of distilled water respectively. Application of NAA was done at 10 days interval and was applied at 20, 30, and 40 days after transplanting.

3.10 Transplanting of seedlings

Healthy and uniform sized thirty days old seedlings were transplanted in the main field on November 20, 2019. The seedlings were uprooted carefully from the seedbed to avoid any damage to the root system. To minimize root damage of the seedlings the seedbed was watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. During transplanting a spacing of 60 cm x 45 cm between row to row and plant to plant were maintained. Thus each unit plot accommodated 6 plants. The seedlings were watered immediately after transplanting. The young transplanted seedlings

were shaded by banana leaf sheath during the day time to protect them from scorching sunshine upto 06 days until they were set in the soil. Transplanted seedlings were kept open at night to allow them for receiving dew. A number of seedlings were also planted on the same day in the border of the experiment plots for gap filling.

3.11 Intercultural operation

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

3.12 Irrigation

Light over-head irrigation was provided with a watering can to the plots immediately after transplanting. Irrigation was also applied when necessary. As a consequence, the amount of irrigation water was calculated from the amount of water discharged from the hosepipe per minute.

3.13 Gap filling

Dead, injured and week seedlings were replaced by healthy one from the stock kept on the border line of the experimental plot. Those seedlings were re-transplanted with a big mass of soil with roots to minimize transplanting shock. Replacement was done with healthy seedling having balls of earth with were also planted on the same date onborder line. The transplanted seedlings were provided shading and watered for 7 days continued for the proper establishment of the seedlings.

3.14 Weeding

Weeds were found in the plots and weeding was done three times in these plots considering the optimum time for removal.

3.15 Plant protection

The crop was protected from the attack of insect-pest by spraying Malathion 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.

3.16 Harvesting

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

3.17 Data collection

The data were collected from the inner rows of plants of each treatment to avoid the border effect. In each unit plot, 3 plants were selected at random for data collection. Data were collected in respect of the plant growth characters and yield of Chinese cabbage. Data on plant however, for gross yields per plot all the 3 plants of each unit plot were considered. All other parameters were recorded at harvest. The following parameters were set up for recording data and for the interpretation of the results. Data were recorded on the following parameters.

3.17.1 Plant height

The height of plant was recorded in centimeter (cm) at 20, 35, 50 days after transplanting (DAT) and at harvest by using a meter scale. The height was measured from the ground level to the tip of the growing point of an individual plant. Mean value of the 3 selected plants was calculated for each unit plot.

3.17.2 Plant spread

The spread of plant was measured with a meter scale as the horizontal distance covered by the plant. The data were recorded from randomly 3 selected plants at 20, 35, 50 days after transplanting and at harvest and mean value was counted and was expressed in centimeter (cm).

3.17.3 Number of unfolded leaves per plant

Number of unfolded leaves per plant was counted at 20, 35, 50 DAT and at harvest from 3 plants and mean value was recorded accurately.

3.17.4 Number of folded leaves per plant

Number of folded leaves per plant was counted at 20, 35, 50 DAT and at harvest from 3 plants and mean value was recorded.

3.17.5 Number of roots per plant

Main roots were washed out by water for removing soil from 3 sample selected plants after harvest. Then the numbers of lateral roots of the plants were counted and the mean value per plant was calculated.

3.17.6 Length of root

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

3.17.7 Length of stem

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

3.17.8 Diameter of stem

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

3.17.9 Days from transplanting to initiation of head

Days from transplanting to initiation of head formation was counted from the date of transplanting to the initiation of head formation and was recorded as treatment wise.

3.17.10 Days from transplanting to head maturity

Days from transplanting to head maturity was counted from the date of seed transplanting to the optimum condition for the harvest.

3.17.11 Diameter of head

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

3.17.12 Thickness of head

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

3.17.13 Fresh weight of unfolded leaves per plant

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

3.17.14 Fresh weight of head per plant

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

3.17.15 Fresh weight of total plant

The fresh weight of plant at harvest was recorded as the average of 3 plants selected at random from each unit plot. The weight of the total plant was recorded immediately after harvest.

3.17.16 Dry matter content of head

A sample of one hundred grams chopped head from 3 selected plants was dried freshly in the direct sun light for two days and then it was dried in an oven at 65°C for 72 hours, until constant weight was achieved. The dry weight of the sample was recorded in gram and the mean value was calculated. Then the percent dry matter content in heads was calculated by using following formula.

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

3.17.17 Gross yield per plot

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

3.17.18 Gross yield per hectare

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

3.18 Statistical analysis

'Hie data obtained for different characters were statistically analyzed to find out the influence of seedling age and naphthalene acetic acid on growth and yield of Chinese cabbage. The analysis of variance was performed by using

MSTAT Program. The significance of the difference among the treatment combinations means was estimated by DMRT (Duncan's Multiple Range Test) at 5% level of probability (Gomez and Gomez, 1984).

3.19 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of seedling age and NAA hormone. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 13% for six months. The market price of cabbage was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

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

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to find out the effect of different levels of naphthalene acetic acid (NAA) and seedling age on the growth and yield of Chinese cabbage. The analysis of variance (ANOVA) of the data on different yield contributing characters and yield of Chinese cabbage are given in Appendix III-IX. The results have been presented and discussed, and possible interpretations have been given under the following headings-

4.1 Plant height

Seedling age of Chinese cabbage showed significant variation in terms of plant height at 20, 35, 50 DAT and at harvest (Appendix III). The tallest plant (24.21 cm) was recorded from 25 days of seedling for A_2 which was closely followed (23.08 cm) by A_1 as 15 days of seedling and the shortest (22.51 cm) plant was found from A_3 as 35 days of seedling at 20 DAT (Figure 2). At 35 DAT, the tallest (32.46 cm) plant was found from A_2 which was statistically similar (31.09 cm) with A_1 and the shortest (30.52 cm) plant was found from the A_3. The tallest (40.72 cm) plant was recorded from A_2 which was statistically similar (39.08 cm) with A_1 and the shortest (38.53 cm) plant was from A_3 at 50 DAT. At harvest, the tallest plant (45.88 cm) was recorded from A_2 which was statistically identical (44.07 cm) with A_1 and the shortest (43.75 cm) was obtained from A_3. From the results it was found that 25 days old seedlings increase the plant height comparing with the 15 days and 35 days old seedlings. Probably, very immature and aged seedling required maximum days to recover transplanting injury. Kler *et al*. (1992) and Kuo and Tsay (1981) reported the similar results from their experiment.

Plant height differed statistically due to the application of different levels of naphthalene acetic acid at 20, 35, 50 DAT and at harvest. At 20 DAT, application of 120 ppm (N_3) of NAA gave the tallest (24.14 cm) plant which was statistically similar (23.37 cm) with N_2 as application of 80 ppm of NAA,

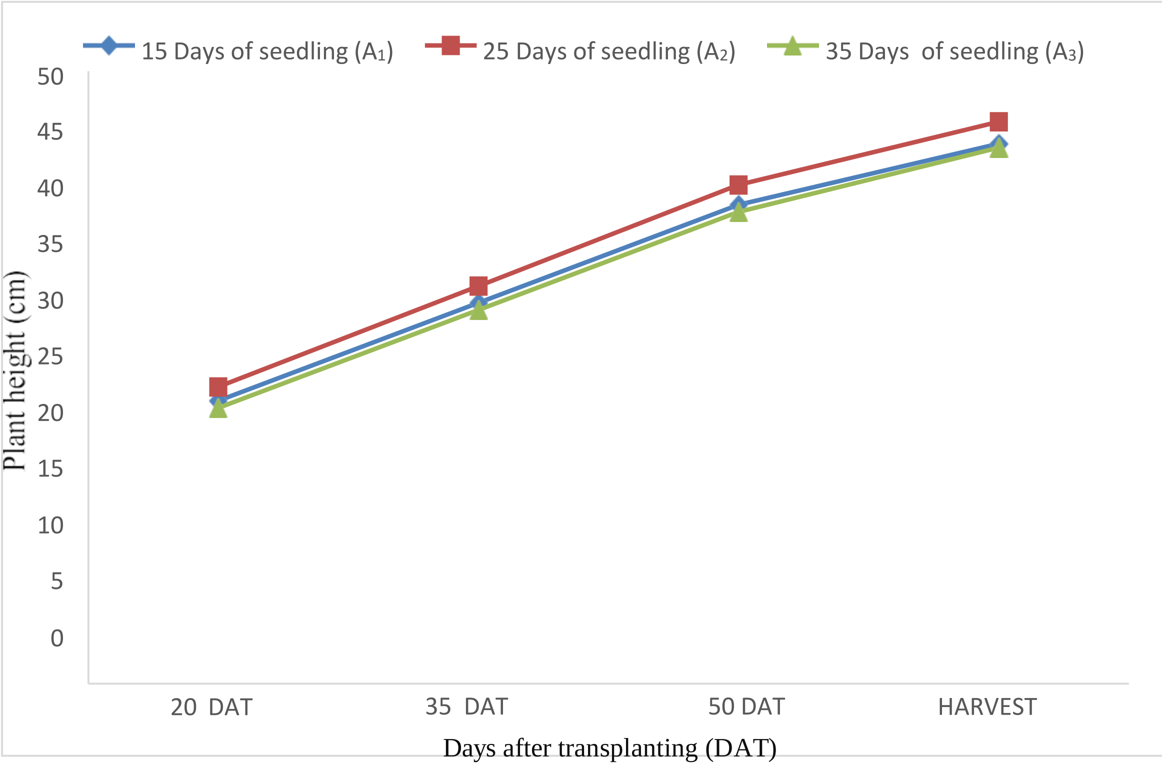


Figure 2: Influence of different seedling ages on plant height of Chinese cabbage

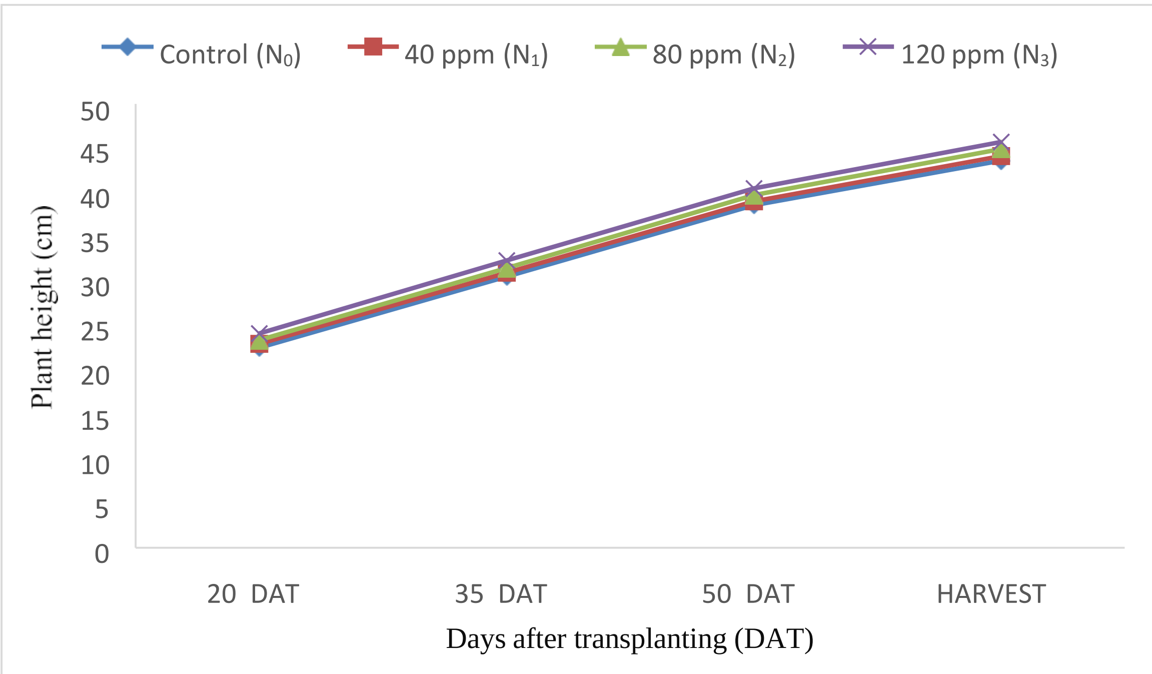


Figure 3: Influence of different levels of NAA on plant height of Chinese cabbage

then 40 ppm (N_1) gave the almost similar result (23.00 cm) while control (N_0) treatment gave the shortest (22.56 cm) plant.

The tallest (32.37 cm) plant was observed in N_3 which was closely followed (31.50 cm) by N_2 and then followed (31.00 cm) by N_1 and the shortest (30.57 cm) plant was found in N_0 at 35 DAT (Figure 3). At 50 DAT, the tallest (40.48 cm) plant was recorded in N_3 which was closely followed (39.71 cm) by N_2 and (39.01 cm) by N_1 and the shortest (38.58 cm) plant was obtained from the N_0. At harvest, N_3 gave the tallest (45.68 cm) plant which was statistically similar (44.90 cm) with N_2, followed (44.09 cm) by N_1 and N_0 gave the shortest (43.59 cm) plant. The results indicated that naphthalene acetic acid generates favorable condition for growth and development as which increases the plant height and among the different 120 ppm and 80 ppm of NAA were most superior than 40 ppm of NAA and control treatment. Chaurasiy *et al.* (2014) recorded maximum plant height from 80 ppm NAA among 40, 80 and 120 ppm of NAA.

Plant height varied significantly by the interaction effect of different levels of NAA and seedling ages at 20, 35, 50 DAT and at harvest. At 20 DAT, the tallest (25.29 cm) plant was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_3N_2 (35 days of seedling and 80 ppm of NAA) showed the shortest (21.58 cm) plant (Table 1). At 35 DAT, significant variations on plant height were also observed among the treatments and the tallest (33.96 cm) plant was observed from A_2N_3 and the shortest (29.57 cm) was from A_3N_2. The tallest plant (42.28 cm) was recorded from A_2N_3 and the shortest plant (37.58 cm) was recorded from A_3N_2 at 50 DAT. The tallest plant (47.61 cm) was recorded from A_2N_3 and the shortest plant (42.73 cm) was found from A_1N_0 (15 days of seedling and control treatment 0 ppm) at harvest.

4.2 Plant spread

Seedling age showed significant variation in terms of spread of plant at 20, 35,

Table 1: Interaction influence of seedling age and different levels of NAA on plant height of Chinese cabbage

Treatment	Plant height (cm) at			
	20 DAT	35 DAT	50 DAT	Harvest
A_1N_0	21.70 ef	29.70 ef	37.70 de	42.73 e
A_1N_1	22.80 de	30.81 cde	38.83 bcd	43.84 bcde
A_1N_2	23.78 bcd	31.81 cd	39.77 bc	44.74 bc
A_1N_3	24.04 bc	32.04 bc	40.04 b	44.97 b
A_2N_0	23.36 cd	31.35 cd	39.38 bc	44.38 bc
A_2N_1	23.44 cd	31.43 cd	39.44 bc	44.43 bc
A_2N_2	24.76 ab	33.11 ab	41.77 a	47.07 a
A_2N_3	25.29 a	33.96 a	42.28 a	47.61 a
A_3N_0	22.63 def	30.65 def	38.66 cde	43.67 cde
A_3N_1	22.75 def	30.74 def	38.77 cde	43.99 bcd
A_3N_2	21.58 f	29.57 f	37.58 e	42.89 de
A_3N_3	23.09 cd	31.11 cd	39.12 bc	44.47 bc
LSD (0.05)	1.2027	1.2309	1.2222	1.2195
Level of significance	*	**	**	**
CV (%)	3.05	2.32	1.83	1.62

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling
A_2: 25 days of seedling
A_3: 35 days of seedling

N_0: 0 ppm (control)
N_1: 40 ppm of NAA
N_2: 80 ppm of NAA
N_3: 120 ppm of NAA

50 DAT and at harvest (Appendix IV). The maximum (31.59 cm) plant spread was recorded from 25 days of seedling (A_2) which was closely followed (29.26 cm) by 15 days of seedling (A_1) and the minimum (29.00 cm) was found from 35 days of seedling (A_3) at 20 DAT (Figure 4). At 35 DAT, the maximum (41.22 cm) plant spread was recorded from A_2 which was statistically similar (40.02 cm) to that of A_1 and the minimum (39.51 cm) was from A_3. The maximum (48.22 cm) plant spread was recorded from A_2 which was closely followed (47.11 cm) by A_1 and the minimum (46.51 cm) was observed from A_3 at 50 DAT. At harvest, the maximum (55.45 cm) plant spread was recorded from A_2 which was statistically similar (54.30 cm) to that of A_1 and the minimum (53.69 cm) was from A_3.

Plant spread differed statistically due to the application of different levels of naphthalene acetic acid at 20, 35, 50 DAT and at harvest. At 20 DAT, application of 120 ppm (N_3) of NAA gave the maximum (31.33 cm) plant spread which was statistically similar (30.38 cm) with N_2 as application of 80 ppm of NAA, then 40 ppm (N_1) gave the almost similar result (29.58 cm) while application of control (N_0) treatment gave the minimum (28.50 cm) plant spread. The maximum (41.12 cm) plant spread was observed in N_3 which was closely followed (40.38 cm) by N_2 and then followed (39.97 cm) by N_1 and the minimum (39.51 cm) plant spread was found in N_0 at 35 DAT (Figure 5). At 50 DAT, the maximum (48.13 cm) plant spread was recorded in N_3 which was closely followed (47.38 cm) by N_2 and (47.04 cm) by N_1 and the minimum (46.57 cm) plant spread was obtained from the N_0. At harvest, N_3 gave the maximum (55.36 cm) plant spread which was statistically similar (54.46 cm) with N_2, followed (54.11 cm) by N_1 and N_0 gave the minimum (53.99 cm) plant spread. The results indicated that naphthalene acetic acid generates favorable condition for growth and development as which increases the plant spread and among the different 120 ppm and 80 ppm of NAA were the maximum (42.27 cm) plant spread was observed from A_2N_3 and the minimum most superior than 40 ppm of NAA and control treatment.

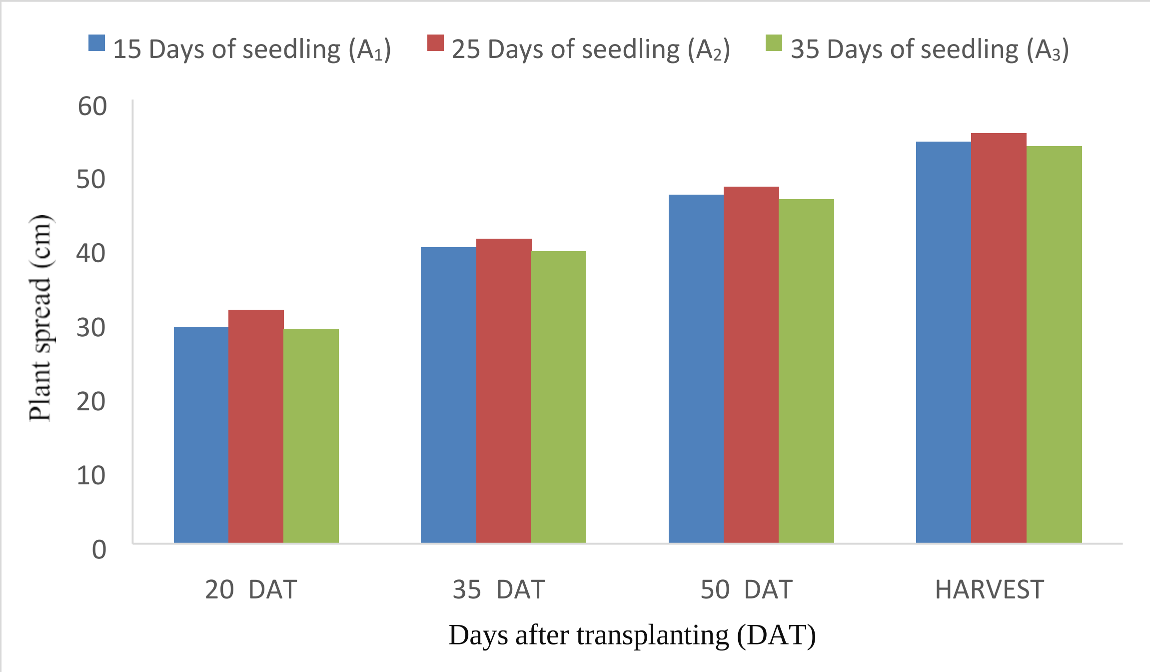


Figure 4: Influence of different seedling ages on plant spread of Chinese cabbage

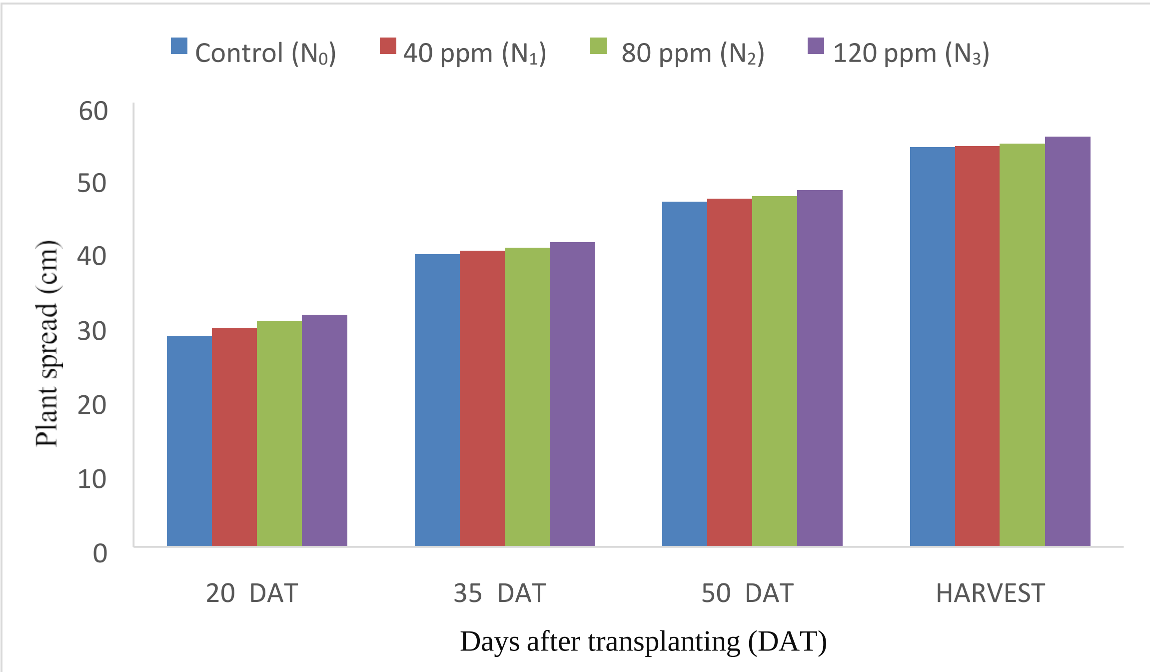


Figure 5: Influence of different levels of NAA on plant spread of Chinese cabbage

Table 2: Interaction influence of seedling age and different levels of NAA on plant spread of Chinese cabbage

Treatment	Plant spread (cm) at			
	20 DAT	35 DAT	50 DAT	Harvest
A_1N_0	28.15 fg	38.55 e	45.70 ef	52.67 e
A_1N_1	28.67 f	39.72 de	46.92 cde	54.37 bcd
A_1N_2	29.73 cd	40.78 bcd	47.78 bcd	54.79 bc
A_1N_3	30.48 bc	41.02 bc	48.03 bc	55.38 b
A_2N_0	29.62 de	40.38 cd	47.39 cd	54.37 bcd
A_2N_1	31.16 b	40.44 cd	47.44 cd	54.77 bc
A_2N_2	32.50 a	41.78 ab	48.78 ab	55.67 ab
A_2N_3	33.10 a	42.27 a	49.28 a	56.98 a
A_3N_0	27.74 g	39.61 de	46.63 def	54.94 bc
A_3N_1	28.92 ef	39.75 de	46.75 def	53.18 de
A_3N_2	28.92 ef	38.58 e	45.59 f	52.92 de
A_3N_3	30.43 bc	40.08 cd	47.10 cd	53.72 cde
LSD (0.05)	0.7743	1.2175	1.2280	1.4970
Level of significance	*	**	*	**
CV (%)	1.53	1.79	1.53	1.62

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling

A_2: 25 days of seedling

A_3: 35 days of seedling

N_0: 0 ppm (control)

N_1: 40 ppm of NAA

N_2: 80 ppm of NAA

N_3: 120 ppm of NAA

Chaurasiy *et al*. (2014) recorded almost similar result from 80 ppm NAA gave superior result among 40, 80 and 120 ppm NAA.

Interaction effect of different seedling ages and naphthalene acetic acid varied significantly in terms of plant spread at 20, 35, 50 DAT and at harvest. At 20 DAT, the maximum (33.10 cm) plant spread was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_3N_0 (35 days of seedling and control treatment 0 ppm) showed the minimum (27.74 cm) plant spread (Table 2). At 35 DAT, the maximum (42.27 cm) plant spread was observed from A_2N_3 and the minimum (38.55 cm) was from A_1N_0 (15 days of seedling and control treatment 0 ppm). The maximum plant spread (49.28 cm) was recorded from A_2N_3 and the minimum plant spread (45.59 cm) was recorded from A_3N_2 at 50 DAT. The maximum plant spread (56.98 cm) was recorded from A_2N_3 and the minimum plant spread (52.67 cm) was found from A_1N_0 at harvest.

4.3 Number of unfolded leaves per plant

Number of unfolded leaves per plant at 20, 35, 50 DAT and at harvest showed significant differences for different seedling age (Appendix V). The maximum number of unfolded leaves (10.00) per plant was recorded from 25 days of seedling (A_2) which was closely followed (8.50) by 15 days of seedling (A_1) and the minimum (8.37) was found from 35 days of seedling (A_3) at 20 DAT (Figure 6). At 35 DAT, the maximum (12.15) number of unfolded leaves per plant was recorded from A_2 which was statistically similar (10.88) to that of A_1 and the minimum (10.75) was from A_3. The maximum (15.01) number of unfolded leaves per plant was recorded from A_2 which was closely followed (13.52) by A_3 and the minimum (13.39) was observed from A_1 at 50 DAT. At harvest, the maximum (18.06) number of unfolded leaves per plant was recorded from A_2 which was statistically similar (16.41) to that of A_1 and the minimum (16.40) was from A_3.

Number of unfolded leaves per plant differed statistically due to the application of different levels of naphthalene acetic acid at 20, 35, 50 DAT and at harvest. At 20 DAT, application of 120 ppm (N_3) of NAA gave the maximum (9.49) number of unfolded leaves per plant which was statistically similar (8.99) with N_1 as application of 40 ppm of NAA, then 80 ppm (N_2) gave the almost similar result (8.98) while application of control (N_0) treatment gave the minimum (8.37) number of unfolded leaves per plant (Figure 7). The maximum (12.31) number of unfolded leaves per plant was observed in N_3 which was closely followed (11.26) by N_3 and then followed (11.20) by N_1 and the minimum (10.28) number of unfolded leaves per plant was found in N_0 at 35 DAT. At 50 DAT, the maximum (14.53) number of unfolded leaves per plant was recorded in N_3 which was closely followed (13.99) by N_2 and (13.98) by N_1 and the minimum (13.40) number of unfolded leaves per plant was obtained from the N_0.

At harvest, N_2 gave the maximum (17.25) number of unfolded leaves per plant which was statistically similar (17.19) which increases the number of unfolded leaves per plant and among the with N_3, followed (17.11) by N_1 and N_0 gave the minimum (16.26) number of unfolded leaves per plant. The results indicated that naphthalene acetic acid generates favorable condition for growth and development as different 80 ppm and 120 ppm of NAA were most superior than 40 ppm of NAA and control treatment.

Interaction effect of different seedling age and naphthalene acetic acid varied significantly in terms of number of unfolded leaves per plant at 20, 35, 50 DAT and at harvest. At 20 DAT, the maximum (10.82) number of unfolded leaves per plant was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment 0 ppm) showed the minimum (7.32) number of unfolded leaves per plant (Table 3). At 35 DAT, significant variations on the number of unfolded leaves per plant was also observed among the treatments and the maximum (13.55) number

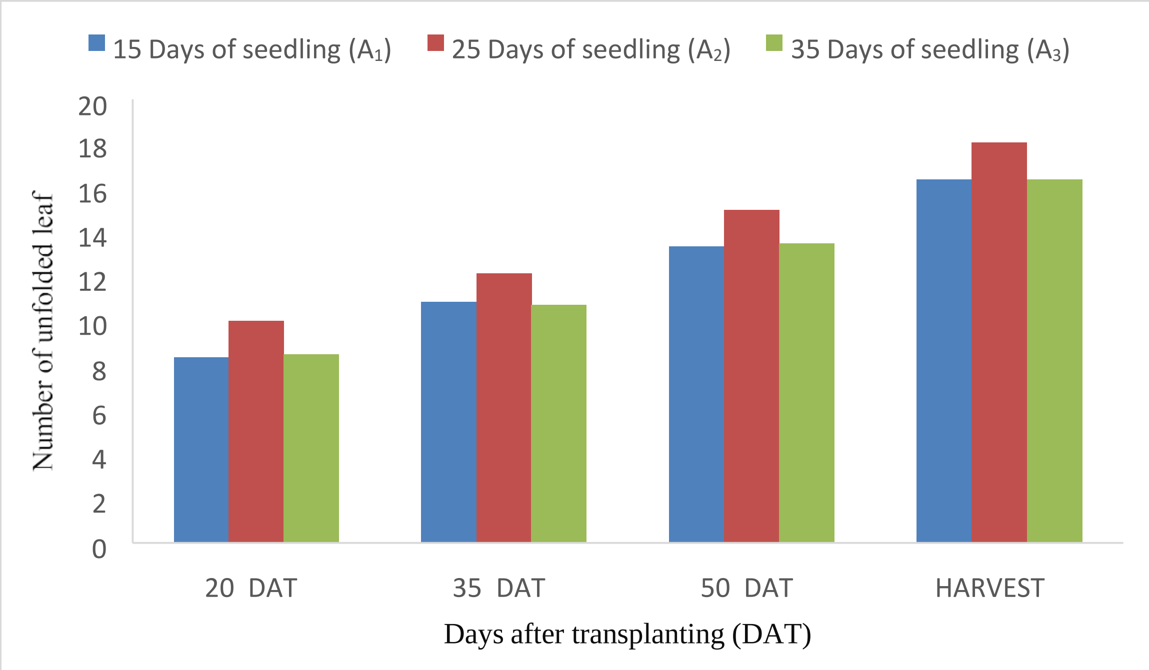


Figure 6: Influence of different seedling ages on number of unfolded leaves of Chinese cabbage

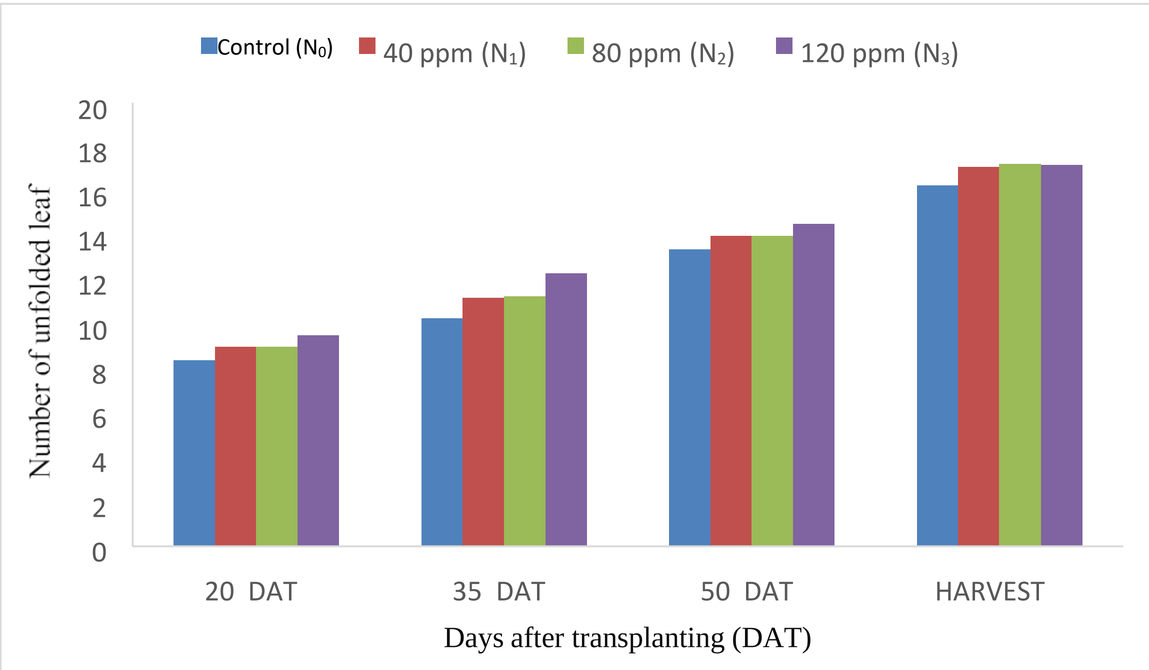


Figure 7: Influence of different levels of NAA on number of unfolded leaves of Chinese cabbage

Table 3: Interaction influence of seedling age and different levels of NAA on number of unfolded leaves of Chinese cabbage

Treatment	Number of unfolded leaves (cm) at			
	20 DAT	35 DAT	50 DAT	Harvest
A_1N_0	7.32 d	9.35 f	12.32 e	15.33 e
A_1N_1	8.46 c	10.95 de	13.43 cd	17.13 bcd
A_1N_2	8.60 c	11.09 cde	13.64 c	17.06 bcd
A_1N_3	9.09 bc	12.12 bc	14.16 bc	16.12 cde
A_2N_0	8.91 bc	10.90 de	13.92 bc	17.24 bc
A_2N_1	9.55 b	11.61 bcd	14.57 b	17.39 b
A_2N_2	10.75 a	12.55 ab	15.74 a	18.76 a
A_2N_3	10.82 a	13.55 a	15.83 a	18.86 a
A_3N_0	8.89 bc	10.60 de	13.96 bc	16.23 bcde
A_3N_1	8.96 bc	11.03 cde	13.95 bc	16.82 bcd
A_3N_2	7.60 d	10.13 ef	12.59 de	15.94 de
A_3N_3	8.57 c	11.25 cde	13.59 c	16.59 bcd
LSD (0.05)	0.8327	1.1351	0.8617	1.2037
Level of significance	**	*	**	*
CV (%)	5.49	5.95	3.64	4.19

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling

A_2: 25 days of seedling

A_3: 35 days of seedling

N_0: 0 ppm (control)

N_1: 40 ppm of NAA

N_2: 80 ppm of NAA

N_3: 120 ppm of NAA

of unfolded leaves per plant was observed from A_2N_3 and the minimum (9.35) was from A_1N_0 (15 days of seedling and control treatment 0 ppm). The maximum (15.83) number of unfolded leaves per plant was recorded from A_2N_3 and the minimum (12.32) number of unfolded leaves per plant was recorded from A_1N_0 at 50 DAT. The maximum (18.86) number of unfolded leaves per plant was recorded from A_2N_3 and the minimum (15.33) number of unfolded leaves per plant was found from A_1N_0 at harvest.

4.4 Number of folded leaves per plant

Number of folded leaves per plant at 20, 35, 50 DAT and at harvest showed significant differences for different seedling age (Appendix VI). The maximum number of folded leaves (7.05) per plant was recorded from 25 days of seedling (A_2) which was closely followed (5.59) by 35 days of seedling (A_3) and the minimum (5.38) was found from 15 days of seedling (A_1) at 20 DAT (Figure 8). At 35 DAT, the maximum (12.04) number of folded leaves per plant was recorded from A_2 which was statistically similar (10.58) to that of A_3 and the minimum (10.40) was from A_1. The maximum (17.05) number of folded leaves per plant was recorded from A_2 which was closely followed (15.59) by A_3 and the minimum (15.39) was observed from A_1 at 50 DAT. At harvest, the maximum (22.06) number of folded leaves per plant was recorded from A_2 which was statistically similar (20.41) to that of A_1 and the minimum (20.40) was from A_3.

Number of folded leaves per plant differed statistically due to the application of different levels of naphthalene acetic acid at 20, 35, 50 DAT and at harvest. At 20 DAT, application of 120 ppm (N_3) of NAA gave the maximum (6.78) number of folded leaves per plant which was statistically similar (6.22) with N_2 as application of 80 ppm of NAA, then 40 ppm (N_1) gave the almost similar result (5.82) while application of control (N_0) treatment gave the minimum (5.19) number of folded leaves per plant (Figure 9). The maximum (11.79) number of folded leaves per plant was observed in N_3 which was closely followed (11.22) by N_2 and then followed (10.83) by N_1 and the minimum

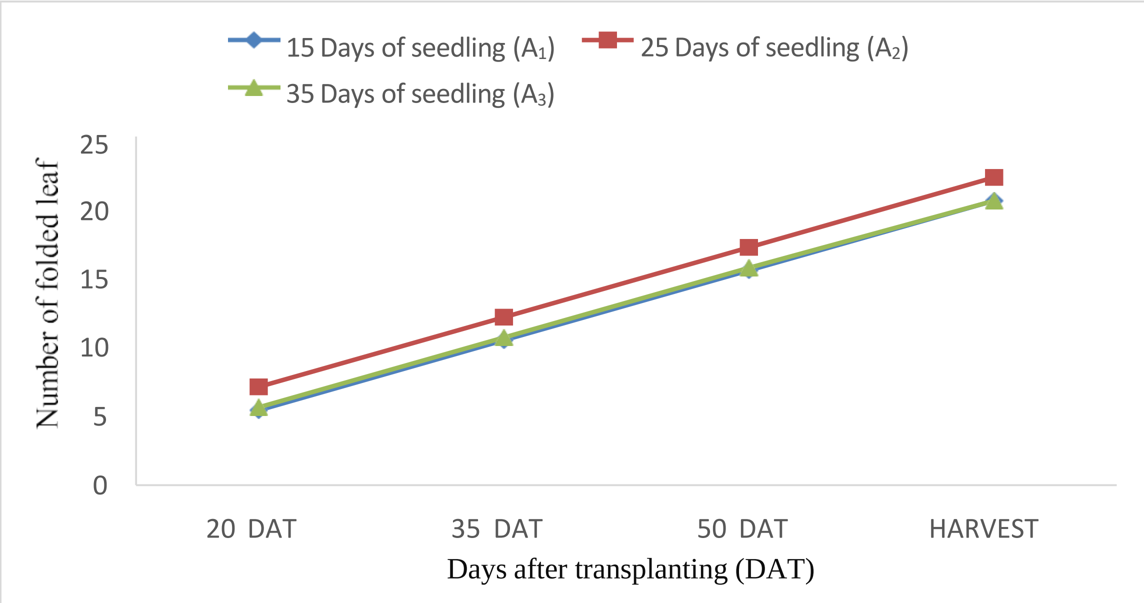


Figure 8: Influence of seedling age on number of folded leaves of Chinese cabbage

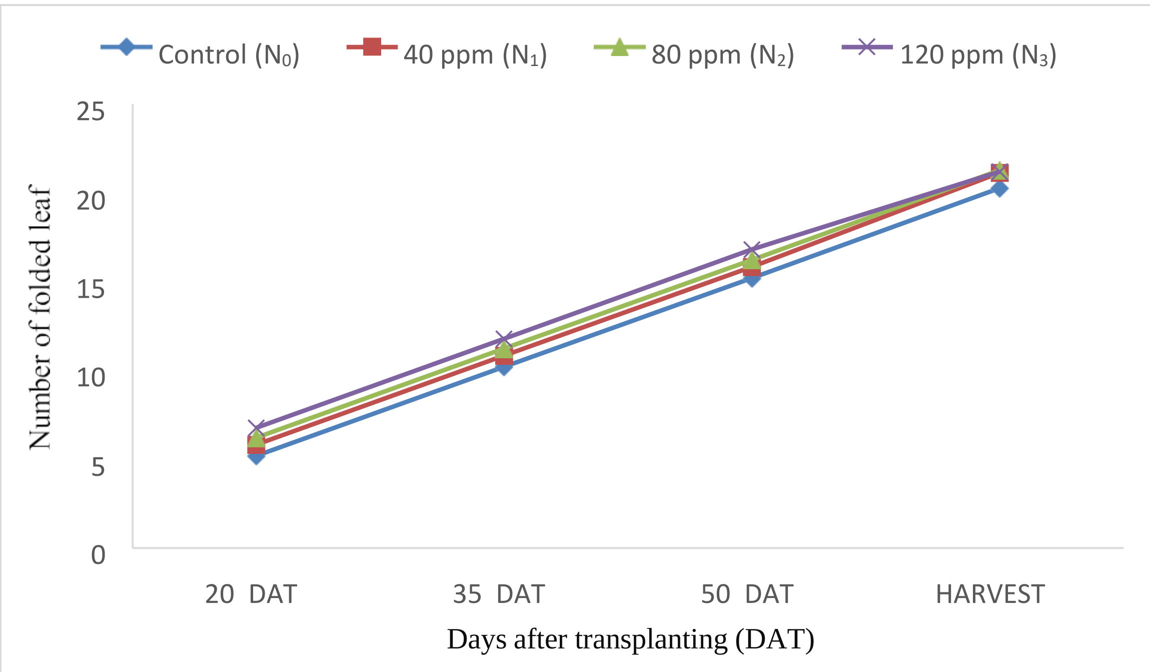


Figure 9: Influence of different levels of NAA on number of folded leaves of Chinese cabbage

(10.19) number of folded leaves per plant was found in N_0 at 35 DAT. At 50 DAT, the maximum (16.81) number of folded leaves per plant was recorded in N_3 which was closely followed (16.23) by N_2 and (15.82) by N_1 and the minimum (15.19) number of folded leaves per plant was obtained from the N_0. At harvest, N_2 gave the maximum (21.26) number of folded leaves per plant which was statistically similar (21.19) with N_3, followed (21.11) by N_1 and N_0 gave the minimum (20.26) number of folded leaves per plant. The results indicated that naphthalene acetic acid generates favorable condition for growth and development as which increases the number of folded leaves per plant and among the different 80 ppm and 120 ppm of NAA were most superior than 40 ppm of NAA and control treatment.

Interaction effect of different seedling age and naphthalene acetic acid varied significantly in terms of number of folded leaves at 20, 35, 50 DAT and at harvest. At 20DAT, the maximum (7.80) number of folded leaves per plant was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment 0 ppm) showed the minimum (4.54) number of folded leaves per plant (Table 4).

At 35 DAT, significant variations on the number of folded leaves per plant was also observed among the treatments and the maximum (12.79) number of folded leaves per plant was observed from A_2N_3 and the minimum (9.54) was from A_1N_0 (15 days of seedling and control treatment 0 ppm). The maximum (17.82) number of folded leaves per plant was recorded from A_2N_3 and the minimum (14.55) number of folded leaves per plant was recorded from A_1N_0 at 50 DAT. The maximum (22.85) number of folded leaves per plant was recorded from A_2N_3 and the minimum (19.30) number of folded leaves per plant was found from A_1N_0 at harvest.

4.5 Number of roots per plant

Number of roots per plant showed a significant difference for different seedling age (Appendix VII). The maximum (24.07) number of roots per plant was recorded from 25 days of seedling (A_2) which was closely followed

Table 4: Interaction influence of seedling age and different levels of NAA on number of folded leaves of Chinese cabbage

Treatment	Number of folded leaves (cm) at			
	20 DAT	35 DAT	50 DAT	Harvest
A_1N_0	4.54 e	9.54 f	14.55 e	19.30 e
A_1N_1	4.91 e	9.94 f	14.91 e	21.14 bcd
A_1N_2	5.87 bcd	10.89 bcd	15.88 bcd	21.07 bcd
A_1N_3	6.19 bc	11.23 bc	16.24 bc	20.12 cde
A_2N_0	5.92 bcd	10.92 bcd	15.89 bcd	21.26 bc
A_2N_1	6.72 b	11.73 b	16.72 b	21.39 b
A_2N_2	7.74 a	12.74 a	17.75 a	22.75 a
A_2N_3	7.80 a	12.79 a	17.82 a	22.85 a
A_3N_0	5.13 de	10.12 def	15.12 de	20.23 bcde
A_3N_1	5.82 cd	10.83 cde	15.82 cd	20.82 bcd
A_3N_2	5.06 de	10.04 ef	15.05 de	19.96 de
A_3N_3	6.36 bc	11.35 bc	16.36 bc	20.61 bcd
LSD (0.05)	0.8759	0.8463	0.8493	1.2022
Level of significance	*	*	*	*
CV (%)	8.61	4.54	3.13	3.39

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling

A_2: 25 days of seedling

A_3: 35 days of seedling

N_0: 0 ppm (control)

N_1: 40 ppm of NAA

N_2: 80 ppm of NAA

N_3: 120 ppm of NAA

(22.42) by 15 days of seedling (A_1) and the minimum (22.39) was found from 35 days of seedling (A_3). From the results it was observed that the optimum aged seedling increases the number of roots per plant with ensuring optimum growth and development (Table 5).

A statistically significant variation was recorded in terms of number of roots per plant due to the different concentrations of naphthalene acetic acid. 80 ppm of NAA (N_2) gave the maximum (23.27) number of roots per plant which was closely followed (23.19) by 120 ppm of NAA (N_3) and (23.12) by 40 ppm of NAA (N_1) and application of control treatment 0 ppm (N_0) showed the minimum (22.26) number of roots per plant (Table 5). Leonard (1962) reported significant effect on number of roots per plant for different type of growth hormone.

Interaction effect of different seedling ages and naphthalene acetic acid showed significant variation in terms of number of roots per plant under the present trial. The maximum (24.86) number of roots per plant was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_2N_3 (15 days of seedling and control treatment) gave the minimum (21.33) number of roots per plant (Table 6). The results indicated combined effect of optimum aged seedling and NAA increase the growth and development of plant which ensure the maximum number of roots per plant.

4.6 Length of root

Length of root showed a significant difference for different seedling ages (Appendix VII). The tallest (17.03) length of root was recorded from 25 days of seedling (A_2) which was followed (15.42) by 15 days of seedling (A_1) and the shortest (15.39) was found from 35 days of seedling (A_3) which is close to A_1. From the results it was observed that the optimum aged seedling increases the length of root with ensuring optimum growth and development (Table 5).

A statistically significant variation was recorded in terms of length of root due to the different concentrations of naphthalene acetic acid. 80 ppm of NAA

(N_2) gave the tallest (16.24) length of root which was closely followed (16.17) by 120 ppm of NAA (N_3) and (16.11) by 40 ppm of NAA (N_1) and control treatment 0 ppm (N_0) showed the shortest (15.26) length of root (Table 5). Magnusson (2002) reported significant effect on length of root for different type of growth hormone.

Interaction effect different seedling age and naphthalene acetic acid showed significant variation in terms of length of root under the present trial. The tallest (17.80) length of root was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment) gave the shortest (14.34) length of root (Table 6). The results indicated combined effect of optimum aged seedling and naphthalene acetic acid increase the growth and development of plant which ensure the tallest length of root.

4.7 Length of stem

Length of stem showed a significant difference for different seedling age (Appendix VII). The tallest (3.24) length of stem was recorded from 25 days of seedling (A_2) which was closely followed (2.88) by 35 days of seedling (A_3) and the shortest (2.85) was found from 15 days of seedling (A_1). From the results it was observed that the optimum aged seedling increases the length of stem with ensuring optimum growth and development (Table 5).

A statistically significant variation was recorded in terms of length of stem due to the different concentrations of naphthalene acetic acid. 120 ppm of NAA (N_3) gave the tallest (3.05) length of stem which was closely followed (3.02) by 80 ppm of NAA (N_2) and (2.98) by 40 ppm of NAA (N_1) and control treatment 0 ppm (N_0) showed the shortest (2.91) length of stem (Table 5).

Interaction effect different seedling age and naphthalene acetic acid showed significant variation in terms of length of stem under the present trial. The tallest (3.50) length of stem was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment) gave the shortest (2.76) length of stem under the present trial (Table 6). The results indicated combined effect of optimum aged seedling and naphthalene acetic acid increase the growth and development of plant which ensure the tallest length of stem.

4.8 Diameter of stem

Diameter of stem showed a significant difference for different seedling age (AppendixVII). The maximum (1.85) diameter of stem was recorded from 25 days of seedling(A_2) which was closely followed (1.49) by 35 days of seedling (A_3) and the minimum (1.32) was found from 15 days of seedling (A_1). From the results it was observed that the optimum aged seedling increases the diameter of stem with ensuring optimum growth and development (Table 5). Opena *et al*. (1988), Talekar and Selleck (1982) also recorded the maximum diameter of stem earlier in their experiment with 25 days old seedling.

A statistically significant variation was recorded in terms of diameter of stem due to the different concentrations of naphthalene acetic acid. 120 ppm of NAA (N_3) gave the maximum (1.71) diameter of stem which was closely followed (1.56) by 80 ppm of NAA (N_2) and (1.51) by 40 ppm of NAA (N_1) and application of control treatment 0 ppm (N_0) showed the minimum (1.43) diameter of stem (Table 5).

Interaction effect different seedling age and naphthalene acetic acid showed significant variation in terms of diameter of stem under the present trial. The maximum (2.20) diameter of stem was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment) gave the minimum (1.24) diameter of stem under the present trial (Table 6). The results indicated combined effect of optimum aged seedling and naphthalene acetic acid increase the growth and development of plant which ensure the maximum diameter of stem.

4.9 Days from transplanting to initiation of head

Days from transplanting to initiation of head at harvest a significant variation was recorded for different seedling age (Appendix VIII). The

Table 5: Influence of seedling age and different levels of NAA on root and stem characteristics of Chinese cabbage

Treatment	Number of roots per plant	Length of root (cm)	Length of stem (cm)	Diameter of stem (cm)
Seedling age				
A_1	22.42 b	15.42 b	2.85 b	1.32 c
A_2	24.07 a	17.03 a	3.24 a	1.85 a
A_3	22.39 b	15.39 b	2.88 b	1.49 b
LSD (0.05)	0.6014	0.5970	0.0668	0.0524
Level of significance	**	**	**	**
Naphthalene acetic acid (NAA)				
N_0	22.26 b	15.26 b	2.91 b	1.43 c
N_1	23.12 a	16.11 a	2.98 ab	1.51 b
N_2	23.27 a	16.24 a	3.02 a	1.56 b
N_3	23.19 a	16.17 a	3.05 a	1.71 a
LSD (0.05)	0.6944	0.6894	0.0772	0.0606
Level of significance	*	*	**	**

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling
A_2: 25 days of seedling
A_3: 35 days of seedling

N_0: 0 ppm (control)
N_1: 40 ppm of NAA
N_2: 80 ppm of NAA
N_3: 120 ppm of NAA

Table 6: Interaction influence of seedling age and different levels of NAA on root and stem characteristics of Chinese cabbage

Treatment	Number of roots per plant	Length of roots (cm)	Length of stem (cm)	Diameter of stem (cm)
A_1N_0	21.33 e	14.34 e	2.76 g	1.24 h
A_1N_1	23.14 bc	16.15 bc	2.91 def	1.30 gh
A_1N_2	23.08 bcd	16.09 bcd	2.92 def	1.37 fg
A_1N_3	22.12 cde	15.11 cde	2.80 fg	1.39 fg
A_2N_0	23.25 bc	16.22 bc	3.03 cd	1.60 d
A_2N_1	23.41 b	16.37 b	3.11 c	1.73 c
A_2N_2	24.78 a	17.71 a	3.31 b	1.85 b
A_2N_3	24.86 a	17.80 a	3.50 a	2.20 a
A_3N_0	22.21 bcde	15.22 bcde	2.95 de	1.46 ef
A_3N_1	22.82 bcd	15.81 bcd	2.93 def	1.50 de
A_3N_2	21.93 de	14.92 de	2.82 efg	1.47 ef
A_3N_3	22.59 bcd	15.61 bcd	2.84 efg	1.53 de
LSD (0.05)	1.2027	1.1940	0.1336	0.1049
Level of significance	*	*	**	**
CV (%)	3.09	4.42	2.64	3.99

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling

A_2: 25 days of seedling

A_3: 35 days of seedling

N_0: 0 ppm (control)

N_1: 40 ppm of NAA

N_2: 80 ppm of NAA

N_3: 120 ppm of NAA

minimum (21.57) days was required from transplanting to initiation of head was recorded from 25 days of seedling (A_2) and the maximum (22.95) days was observed from 15 days of seedling (A_1) which was closely followed (22.81 days) with 35 days of seedling (A_3). From the result it was found that both early and late transplanting seedling increase the days from transplanting to initiation of head of Chinese cabbage (Table 7).

A significant variation was recorded in terms of days from transplanting to initiation of head due to the different levels of naphthalene acetic acid. Application of 40 ppm of NAA (N_1) required the minimum (21.77) days from transplanting to initiation of head (Table 7), while 120 ppm of NAA (N_3) required the maximum (23.32) days. Kato (1981) reported that naphthalene acetic acid ensures the favorable condition for the growth and development of Chinese cabbage and the ultimate result is the shortest duration for attaining head formation.

Interaction effect of different seedling age and naphthalene acetic acid showed significant variation in terms of days from transplanting to initiation of head. The minimum (19.17) days from transplanting to initiation of head was recorded from 25 days of seedling and 80 ppm of NAA (A_2N_2), while the 35 days of seedling and control treatment (A_3N_0) gave the maximum (25.34) days from transplanting to initiation of head (Table 8).

4.10 Days from transplanting to head maturity

Days from transplanting to head maturity at harvest a significant variation was recorded for different seedling age (Appendix VIII). The minimum (54.27) days was required from transplanting to head maturity was recorded from 25 days of seedling (A_2) and the maximum (57.01) days was observed from 15 days of seedling (A_1) which was closely followed (56.84) days with 35 days of seedling (A_3). From the results it was found that both early and late transplanting seedling increase the days from transplanting to head maturity of Chinese cabbage (Table 7). Kobryn (1987) reported the similar results from their experiment.

A significant variation was recorded in terms of days from transplanting to head maturity due to the different levels of naphthalene acetic acid. Application of 40 ppm of NAA (N_1) required the minimum (55.03) days from transplanting to head maturity (Table 7), while 120 ppm of NAA (N_3) required the maximum (57.10) days.

Thy and Buntha (2005) reported that naphthalene acetic acid ensures the favorable condition for the growth and development of Chinese cabbage and the ultimate result is the shortest duration for attaining head formation.

Interaction effect of different seedling age and naphthalene acetic acid showed significant variation in terms of days from transplanting to head maturity. The minimum (52.09) days from transplanting to head maturity was recorded from 25 days of seedling and 80 ppm of NAA (A_2N_2), while the 35 days of seedling and control treatment (A_3N_0) gave the maximum (59.90) days from transplanting to head maturity (Table 8).

4.11 Diameter of head

Diameter of head showed a significant difference for different seedling age (Appendix VIII). The maximum (16.02) diameter of head was recorded in from 25 days of seedling (A_2) which was closely followed (14.53) by 35 days of seedling (A_3) and the minimum (14.40) was found from 15 days of seedling (A_1). From the results it was observed that the optimum aged seedling increases the diameter of head with ensuring optimum growth and development (Table 7). Shoemaker (1947) reported maximum diameter of head from the same days old seedlings.

A statistically significant variation was recorded in terms of diameter of head due to the different concentrations of naphthalene acetic acid. 120 ppm of NAA (N_3) gave the maximum (15.53) diameter minimum (15.33) thickness of head under the present trial (Table 7). The results indicated combined effect of head which was closely followed (15.00) by 80 ppm of NAA (N_2) and (14.99) by 40 ppm of NAA (N_1) and control treatment 0 ppm (N_0)

Table 7: Influence of seedling age and different levels of NAA on different yield contributing characters of Chinese cabbage

Treatment	Days from transplanting to initiation of head	Days from transplanting to head maturity	Diameter of head (cm)	Thickness of head (cm)	Fresh weight of unfolded leaves per plant (g)
Seedling age					
A_1	22.95 a	57.01 a	14.40 b	16.40 b	598.56 a
A_2	21.57 c	54.27 c	16.02 a	18.07 a	384.98 c
A_3	22.81 b	56.84 b	14.53 b	16.38 b	491.00 b
LSD (0.05)	0.1254	0.0465	0.4338	0.6029	394.12
Level of significance	**	**	**	**	**
Naphthalene acetic acid (NAA)					
N_0	22.55 b	56.23 b	14.41 c	16.26 b	434.83 b
N_1	21.77 d	55.03 d	14.99 b	17.11 a	506.83 a
N_2	22.14 c	55.79 c	15.00 b	17.25 a	523.29 a
N_3	23.32 a	57.10 a	15.53 a	17.19 a	501.12 a
LSD (0.05)	0.1448	0.0537	0.5009	0.6962	45.509
Level of significance	**	**	**	*	**

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling
A_2: 25 days of seedling
A_3: 35 days of seedling

N_0: 0 ppm (control)
N_1: 40 ppm of NAA
N_2: 80 ppm of NAA
N_3: 120 ppm of NAA

Table 8: Interaction influence of seedling age and different levels of NAA on different yield contributing characters of Chinese cabbage

Treatment	Days from transplanting to initiation of head	Days from transplanting to head maturity	Diameter of head (cm)	Thickness of head (cm)	Fresh weight of unfolded leaves per plant (g)
A_1N_0	22.72 d	56.50 e	13.34 e	15.33 e	510.67 cd
A_1N_1	20.57 f	54.32 h	14.44 cd	17.14 bcd	637.00 a
A_1N_2	23.64 c	57.65 d	14.64 c	17.04 bcd	646.56 a
A_1N_3	24.88 b	59.57 b	15.16 bc	16.10 cde	600.02 ab
A_2N_0	19.59 h	52.29 j	14.93 bc	17.23 bc	290.37 g
A_2N_1	22.52 d	54.58 g	15.58 b	17.40 b	459.88 def
A_2N_2	19.17 i	52.09 k	16.74 a	18.77 a	383.18 f
A_2N_3	25.01 b	58.11 c	16.84 a	18.89 a	406.48 f
A_3N_0	25.34 a	59.90 a	14.95 bc	16.21 bcde	503.44 cd
A_3N_1	22.20 e	56.20 f	14.95 bc	16.79 bcd	423.61 ef
A_3N_2	23.62 c	57.62 d	13.62 de	15.95 de	540.12
A_3N_3	20.08 g	53.63 i	14.60 c	16.59 bcd	496.85 cde
LSD (0.05)	0.2507	0.0931	0.8676	1.2059	78.824
Level of significance	**	**	**	*	**
CV (%)	0.66	0.10	3.42	4.20	9.47

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling

A_2: 25 days of seedling

A_3: 35 days of seedling

N_0: 0 ppm (control)

N_1: 40 ppm of NAA

N_2: 80 ppm of NAA

N_3: 120 ppm of NAA

showed the minimum (14.41) diameter of head (Table 7). Sharma (2001) and Santipracha and Sadoodee (1995) reported the similar results.

Interaction effect different seedling age and naphthalene acetic acid showed significant variation in terms of diameter of head under the present trial. The maximum (16.84) diameter of head was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment) gave the minimum (13.34) diameter of head under the present trial (Table 8). The results indicated combined effect of optimum aged seedling and naphthalene acetic acid increase the growth and development of plant which ensure the maximum diameter of head.

4.12 Thickness of head

Thickness of head showed a significant difference for different seedling age (Appendix VIII). The maximum (18.07) thickness of head was recorded in from 25 days of seedling (A_2) which was closely followed (16.40) by 15 days of seedling (A_1) and the minimum (16.38) was found from 35 days of seedling (A_3). From the results it was observed that the optimum aged seedling increases the thickness of head with ensuring optimum growth and development (Table 7). Singh *et al.* (2001) reported maximum thickness of head from the same days old seedlings.

A statistically significant variation was recorded in terms of thickness of head due to the different concentrations of naphthalene acetic acid. 80 ppm of NAA (N_2) gave the maximum (17.25) thickness of head which was closely followed (17.19) by 120 ppm of NAA (N_3) and (17.11) by 40 ppm of NAA (N_1) and application of control treatment 0 ppm (N_0) showed the minimum (16.26) thickness of head (Table 7). Sitadhani and Bosnyake (1988) reported the similar results.

Interaction effect of different seedling age and naphthalene acetic acid showed significant variation in terms of thickness of head under the present trial. The maximum (18.89) thickness of head was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment) gave the of optimum aged seedling and naphthalene acetic acid increase the growth and development of plant which ensure the maximum thickness of head.

4.13 Fresh weight of unfolded leaves per plant

Fresh weight of unfolded leaves per plant showed a significant variation for different seedling age (Appendix VIII). The maximum (598.56 g) fresh weight of unfolded leaves per plant was recorded from 15 days of seedling (A_1) and the minimum (384.98g) was from (A_2) which was closely followed (491.00 g) by (A_3) (Table 7).

A significant variation was recorded in terms of fresh weight of unfolded leaves per plant due to the different levels of naphthalene acetic acid. Application of 80 ppm of NAA (N_2) significant variation was recorded in terms of fresh weight of unfolded leaves per plant due to the different level of NAA. Application of 80 ppm of NAA (N_2) gave the maximum (523.29 g) fresh weight of unfolded leaves per plant. Application of control treatment (N_0) gave the minimum (434.83 g) which was closely followed (501.12 g) by 120 ppm of NAA (N_3) and (506.83 g) by 40 ppm of NAA (N_1) (Table 7).

Interaction effect of different seedling age and different concentrations of NAA showed significant variation in terms of fresh weight of unfolded leaves per plant under the present trial. The maximum (646.56 g) fresh weight of unfolded leaves per plant was recorded from A_1N_2 (15 days of seedling and 80 ppm of NAA), while A_2N_2 (25 days of seedling and 80 ppm of NAA) gave the minimum (383.18 g) fresh weight of unfolded leaves per plant (Table 8).

4.14 Fresh weight of head per plant

Fresh weight of head per plant showed a significant variation for different seedling age (Appendix IX). The maximum (1.69 kg) fresh weight of head per plant was recorded from 25 days old seedling (A_2) and the minimum (1.35 kg) was from 15 days old seedling (A_1) which was closely followed (1.43 kg) by 35 days old seedling (A_3) (Table 9).

A significant variation was recorded in terms of fresh weight of head per plant due to the different levels of naphthalene acetic acid. Application of 120 ppm of NAA (N_3) significant variation was recorded in terms of fresh weight of head per plant due to the different levels of NAA. Application of 120 ppm of NAA (N_3) gave the maximum (1.53 kg) fresh weight of head per plant. Application of control treatment (N_0) gave the minimum (1.43 kg) which was closely followed (1.49 kg) by 40 ppm of NAA (N_1) and (1.52) by 80 ppm of NAA (N_2) (Table 9).

Interaction effect of different seedling age and different concentrations of NAA showed significant variation in terms of fresh weight of head per plant under the present trial. The maximum (1.87 kg) fresh weight of head per plant was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while A_1N_0 (15 days of seedling and control treatment) gave the minimum (1.28 kg) fresh weight of head per plant (Table 10).

4.15 Fresh weight of total plant

Fresh weight of total plant showed a significant variation for different seedling age (Appendix VIII). The maximum (2.08 kg) fresh weight of total plant was recorded from 25 days of seedling (A_2) and the minimum (1.92 kg) was from 35 days old seedling (A_3) which was closely followed (1.95 kg) by 15 days old seedling (A_1) (Table 9).

A significant variation was recorded in terms of fresh weight of total plant due to the different levels of naphthalene acetic acid. Application of 80 ppm of NAA (N_2) significant variation was recorded in terms of fresh weight of total plant due to the different levels of NAA, while application of 80 ppm of NAA (N_2) gave the maximum (2.04 kg) fresh weight of total plant which was closely followed (2.03 kg) by 120 ppm of NAA (N_3) and (2.00 kg) by 40 ppm of NAA (N_1). Control treatment (N_0) gave the minimum (1.86 kg) fresh weight of total plant (Table 9).

Interaction effect of different seedling age and different concentrations of NAA showed significant variation in terms of fresh weight of total plant under the present trial. The maximum (2.27 kg) fresh weight of total plant was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while A_1N_0 (15 days of seedling and control treatment) gave the minimum (1.79 kg) fresh weight of total plant (Table 10).

4.16 Dry matter content of head

Dry matter content of head showed a significant variation for different seedling ages (Appendix IX). The maximum (13.26%) dry matter content of head was recorded from 25 days of seedling (A_2) and the minimum (11.95%) was found from 35 days of seedling (A_3) followed (12.17%) by 15 days of seedling (A_1) (Table 9). Thonguthaisri (1984) and Guttormsen (1996) reported that seedling age was positively correlated to dry matter (DM) content at harvest.

A statistically non-significant variation was recorded in terms of dry matter content of head due to the different level of naphthalene acetic acid. Application of 120 ppm of NAA (N_3) gave the maximum (12.94%) dry matter content of head closely followed (12.51%) by 80 ppm of NAA (N_2) and (12.48) by 40 ppm of NAA (N_1), while control treatment (N_0) showed the minimum (11.91%) dry matter content of head (Table 9).

Interaction effect of seedling age and different levels of naphthalene acetic acid showed significant variation in terms of dry matter content of head under the present trial. The maximum (14.99 %) dry matter content of head was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment) gave the minimum (11.61%) dry matter content of head (Table 10).

4.17 Gross yield per plot

Significant variation was recorded for different seedling ages in terms of gross yield per plot (Appendix IX). The maximum (12.48 kg) gross yield per plot

Table 9: Influence of seedling age and different levels of NAA on different yield contributing characters of Chinese cabbage

Treatment	Fresh weight of head per plant (kg)	Fresh weight of total plant (kg)	Dry matter contentof head(%)	Gross Yield (kg/plot)	Gross Yield (t/ha)
Seedling age					
A_1	1.35 c	1.95 b	12.17 b	11.71 b	72.26 b
A_2	1.69 a	2.079 a	13.26 a	12.48 a	77.01 a
A_3	1.43 b	1.92 b	11.95 b	11.53 b	71.14 b
LSD (0.05)	0.0601	0.0612	0.3342	0.3670	2.2655
Level of significance	**	**	**	**	**
Naphthalene acetic acid (NAA)					
N_0	1.43 b	1.86 b	11.91 c	11.17 b	68.93 b
N_1	1.49 ab	2.00 a	12.48 b	11.98 a	73.95 a
N_2	1.52 a	2.04 a	12.51 b	12.27 a	75.72 a
N_3	1.53 a	2.03 a	12.94 a	12.19 a	75.27 a
LSD (0.05)	0.0694	0.0706	0.3859	0.4238	2.6160
Level of significance	*	**	**	**	**

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling
A_2: 25 days of seedling
A_3: 35 days of seedling

N_0: 0 ppm (control)
N_1: 40 ppm of NAA
N_2: 80 ppm of NAA
N_3: 120 ppm of NAA

Table 10: Interaction Influence of seedling age and different levels of NAA on different yield contributing characters of Chinese cabbage

Treatment	Fresh weight of head per plant (kg)	Fresh weight of total plant (kg)	Dry matter content of head(%)	Gross Yield (kg/plot)	Gross Yield (t/ha)
A_1N_0	1.28 f	1.79 f	11.61 e	10.72 f	66.18 f
A_1N_1	1.39 def	2.02 bcd	12.49 bcd	12.14 bcd	74.94 bcd
A_1N_2	1.42 de	2.07 bc	12.62 bc	12.42 bc	76.67 bc
A_1N_3	1.32 ef	1.92 de	11.95 cde	11.54 de	71.23 de
A_2N_0	1.56 bc	1.85 ef	11.97 cde	11.08 ef	68.40 ef
A_2N_1	1.61 b	2.07 bc	12.95 b	12.40 bc	76.55 bc
A_2N_2	1.75 a	2.13 b	13.12 b	12.78 b	78.89 b
A_2N_3	1.87 a	2.27 a	14.99 a	13.64 a	84.20 a
A_3N_0	1.45 cd	1.95 cde	12.13 cde	11.70 cde	72.23 cde
A_3N_1	1.48 cd	1.90 ef	11.99 cde	11.40 ef	70.37 ef
A_3N_2	1.39 def	1.93 de	11.78 e	11.60 de	71.61 de
A_3N_3	1.40 de	1.90 ef	11.88 de	11.40 ef	70.37 ef
LSD (0.05)	0.1201	0.1223	0.6684	0.7340	4.5310
Level of significance	**	**	**	**	**
CV (%)	4.75	3.64	3.17	3.64	3.64

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

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

A_1: 15 days of seedling
A_2: 25 days of seedling
A_3: 35 days of seedling

N_0: 0 ppm (control)
N_1: 40 ppm of NAA
N_2: 80 ppm of NAA
N_3: 120 ppm of NAA

was recorded from 25 days of seedling (A_2) which was statistically similar (11.71 kg) with 15 days of seedling (A_1) and the minimum (11.53 kg) was obtained from 35 days of seedling (A_3). From the results it was found that optimum aged seedling increases the gross yield per plot (Table 9).

A significant variation was recorded in terms of gross yield per plot due to the different concentrations of naphthalene acetic acid. Application of 80 ppm of NAA (N_2) performed the highest (12.27 kg) gross yield per plot which was statistically similar (12.19 kg) with 120 ppm of NAA (N_3) and (11.98 kg) by 40 ppm of NAA (N_1), while control treatment (N_0) gave the lowest (11.17 kg) gross yield per plot. The results indicated that NAA increases the growth and development of plant which ensures the maximum yield per plot of Chinese cabbage and 80 ppm of NAA and 120 ppm of NAA were better than 40 ppm of NAA and control treatment (Table 9).

Interaction effect of seedling age and different concentrations of NAA showed significant variation in terms of gross yield per plot under the present trial. The maximum (13.64 kg) gross yield per plot was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment) gave the minimum (10.72 kg) gross yield per plot (Table 10). With the optimum aged seedling and NAA ensure the favorable condition and the ultimate results maximum photosynthesis as well as highest yield.

4.18 Gross yield per hectare

Gross yield per hectare showed a significant variation for different seedling age (Appendix IX). The maximum (77.01 t) gross yield per hectare was recorded from 25 days of seedling (A_2) which was followed (72.26 t) by 15 days of to the seedling (A_1) and the minimum (71.14 t) was obtained from 35 days of seedling (A_3) (Table 9).

A significant variation was recorded in terms of gross yield per hectare due to different levels of naphthalene acetic acid. 80 ppm of NAA (N_2) showed the maximum (75.72 t) gross yield per hectare which was statistically similar

(75.27 t) with 120 ppm of NAA (N_3) and (73.95 t) by 40 ppm of NAA (N_1), while the control treatment (N_0) performed the lowest (68.93 t) gross yield per hectare showed significant variation in terms of gross yield per hectare under the present trial (Table 9).

Interaction effect of seedling age and different levels of naphthalene acetic acid showed significant variation in terms of gross yield per hectare under the present trial. The maximum (84.20 t) gross yield per hectare was recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA), while the A_1N_0 (15 days of seedling and control treatment) gave the minimum (66.18 t) gross yield per hectare (Table 10).

4.19 Economic analysis

Input costs for land preparation, seed cost, fertilizer, thinning, irrigation, and man power required for all the operations from sowing to harvesting were recorded for unit plot and converted into cost per hectare. Prices of Chinese cabbage were considered in market rate basis. The economic analysis was done to find out the gross and net returnand the benefit cost ratio in the present experiment and presented under the following headings-

4.19.1 Gross return

The combination of seedling age and different levels of naphthalene acetic acid showed different gross returns. The highest gross return (Tk. 9,26,200) was obtained from A_2N_3 (25 days of seedling and 120 ppm of NAA) and the second highest gross return (Tk. 8,67,790) was obtained from A_2N_2 (25 days of seedling and 80 ppm of NAA). The lowest gross return (Tk. 7,27,980) was observed A_1N_0 (15 days of seedling and control treatment 0 ppm) (Table 11).

4.19.2 Net return

In case of net return different treatment combinations showed different net returns. The highest net return (Tk. 6,44,765) was obtained from A_2N_3 and the second highest net return (Tk. 5,88,944) was obtained from A_2N_2. The lowest net return (Tk. 4,57,139) was obtained from A_1N_0 (Table 11).

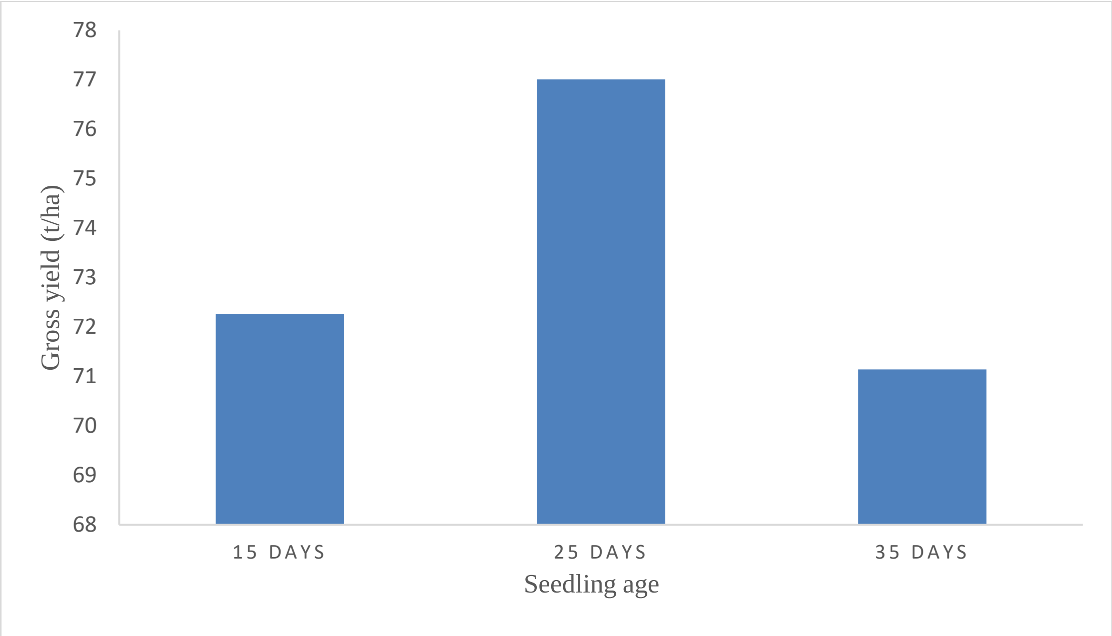


Figure 10: Influence of seedling age on yield of Chinese cabbage

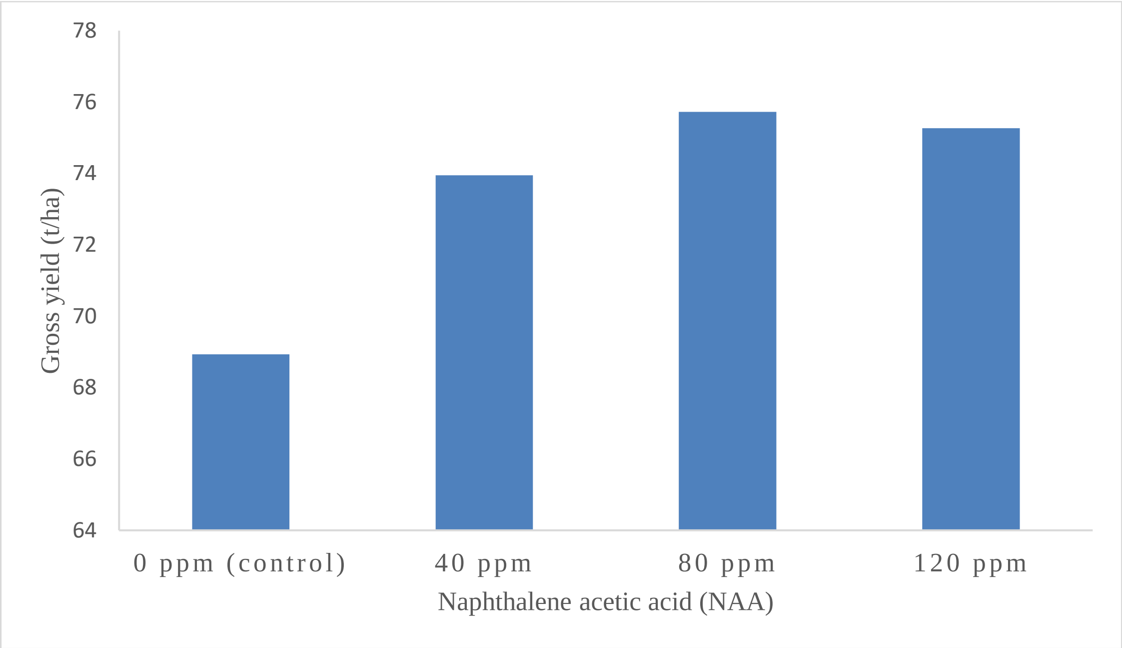


Figure 11: Influence of different levels of NAA on yield of Chinese cabbage

Table 11: Cost and return of Chinese cabbage cultivation as influenced by different seedling age and different level of NAA

Treatment combination	Cost of production (Tk./ha)	Yield of Chinese cabbage (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
A_1N_0	270,841	66.18	727,980	457,139	2.69
A_1N_1	276,256	74.94	824,340	548,084	2.98
A_1N_2	278,846	76.67	843,370	564,524	3.02
A_1N_3	281,435	71.23	783,530	502,095	2.78
A_2N_0	270,841	68.40	752,400	481,559	2.78
A_2N_1	276,256	76.55	842,050	565,794	3.05
A_2N_2	278,846	78.89	867,790	588,944	3.11
A_2N_3	281,435	84.20	926,200	644,765	3.29
A_3N_0	270,841	72.23	794,530	523,689	2.93
A_3N_1	276,256	70.37	774,070	497,814	2.80
A_3N_2	278,846	71.61	787,710	508,864	2.82
A_3N_3	281,435	70.37	774,070	492,635	2.75

4.19.3 Benefit cost ratio

In the combinations of seedling age and different concentrations of naphthalene acetic acid the highest benefit cost ratio (3.29) was obtained from A_2N_3 and the second highest benefit cost ratio (3.11) was estimated from A_2N_2**.** The lowest benefit cost ratio (2.69) was obtained in A_1N_0**.** From economic point of view, it is apparent from the above results that A_2N_3 was more profitable among the treatment combinations (Table 11).

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted in the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2019 to January, 2020 to study the influence of seedling age and NAA on growth and yield of Chinese cabbage. The experiment considered of two factors: Factor A: Seedling age (three levels) such as, A_1= 15 days of seedling, A_2= 25 days of seedling and A_2= 35 days of seedling and Factor B: Naphthalene acetic acid - NAA (four levels) such as, N_0= 0 ppm (control); N_1= 40 ppm of NAA; N_2= 80 ppm of NAA and N_3= 120 ppm of NAA. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield parameters and yield of Chinese cabbage were recorded and analyzed statistically.

Seedling age showed significant differences in all recorded characters. At harvest the tallest (45.88 cm) plant was recorded from A_2 (25 days of seedling) and the shortest (43.75 cm) plant was from A_3 (35 days of seedling). At harvest, the maximum (55.45 cm) plant spread was recorded from A_2 and the minimum (53.69 cm) was found from A_3. The maximum (18.06) number of unfolded leaves per plant was recorded from A_2 and the minimum (16.40) was found from A_3 at harvest.

The maximum (22.06) number of folded leaves per plant was recorded from A_2 and the minimum (20.40) was obtained from A_3. The minimum (21.57) day from transplanting to initiation of head was recorded from 25 days of seedling (A_2) and the maximum (22.95) days was found from 15 days of seedling (A_1). The minimum (54.27) days from transplanting to head maturity was recorded from A_2 and the maximum (57.01) days was obtained from A_1. The maximum (24.07) number of roots per plant was recorded from A_2 and the minimum (22.39) was found from A_3. The tallest (17.03) length of root was recorded from A_2 and the shortest (15.39) was found from A_3. The tallest (3.24) length of stem was recorded from A_2 and the shortest (2.85) was found from A_1. The maximum (1.85) diameter of stem was recorded from A_2 and the minimum (1.32) was found from A_1. The maximum (16.02 cm) diameter of head was recorded from A_2 and the minimum (14.40 cm) was obtained from A_1. The maximum (18.07 cm) thickness of head was recorded from A_2 and the minimum (16.38 cm) was found from A_3. The maximum (13.26%) dry matter content of head was recorded from A_2 and the minimum (11.95%) was recorded from A_3. The maximum (1.69 kg) fresh weight of head per plant was recorded from A_2 and the minimum (1.35 kg) was recorded from A_1. The maximum (77.01 t) gross yield per hectare was recorded from 25 days of seedling (A_2) and the minimum (71.14 t) was found from A_3.

Statistically significant variation was recorded in all recorded characters due to the different levels of naphthalene acetic acid. At harvest, application of 120 ppm of NAA (N_3) gave the tallest (45.68 cm) plant and control treatment 0 ppm (N_0) gave the shortest (43.59 cm) plant. During harvest N_3 showed the maximum (55.36 cm) plant spread, while the N_0 gave the minimum (53.99 cm). The maximum (17.25) number of unfolded leaves per plant was recorded from application of 80 ppm of NAA (N_2) and the minimum (16.26) was found from N_0 at harvest. The maximum (21.26) number of folded leaves per plant was recorded from N_2 and the minimum (20.26) was obtained from N_0. The minimum (21.77) days from transplanting to initiation of head was recorded from N_1 and the maximum (23.32) days was found from N_3.

The minimum (55.03) days from transplanting to head maturity was recorded from N_1 and the maximum (57.10) days was obtained from N_3. The maximum (23.27) number of roots per plant was recorded from N_2 and the minimum (22.26) was found from N_0. The tallest (16.24) length of root was recorded from N_2 and the shortest (15.26) was found from N_0. The tallest (3.05) length of stem was recorded from N_3 and the shortest (2.91) was found from N_0. The maximum (1.71) diameter of stem was recorded from N_3 and the minimum (1.43) was found from N_0. The maximum (15.53 cm) diameter of head was recorded from N_3 and the minimum (14.41 cm) was obtained N_3. The maximum (17.25 cm) thickness of head was recorded from N_2 and the minimum (16.26 cm) was found from N_0. The maximum (12.94%) dry matter content of head was recorded from N_3 and the minimum (11.91%) was recorded from N_0. The maximum (1.53 kg) fresh weight of head per plant was recorded from N_3 and the minimum (1.43 kg) was recorded from N_0. The maximum (75.72 t) gross yield per hectare was recorded from 80 ppm of NAA (N_2) and the minimum (68.93 t) was found from N_0.

Interaction effect between seedling age and different concentrations of naphthalene acetic acid also showed significant differences and the considerable highest value of yield and yield contributing characters were recorded from A_2N_3 (25 days of seedling and 120 ppm of NAA) and A_1N_0 (15 days of seedling and control treatment) gave the lowest value.

The highest gross return (Tk. 9,26,200) and net return (Tk. 6,44,765) were obtained from A_2N_3 (25 days of seedling and 120 ppm of NAA) and the lowest gross return (Tk. 7,27,980) and net return (Tk. 4,57,139) was found from A_1N_0 (15 days of seedling and control treatment). The highest benefit cost ratio (3.29) was obtained from A_2N_3 and the lowest benefit cost ratio (2.69) was found in A_1N_0.

Conclusion

Among the combinations seedling age and of different levels of NAA; 25 days of seedling with 120 ppm of NAA induced superior growth, yield contributing characters and yield of Chinese cabbage as well as highest economic return.

REFERENCES

Abdalla, I. M., Helal, R. M. and Zaki, M. E. (1980). Studies on the effect of some growth regulators on yield and quality of cauliflower. *Ann. Agric. Sci.,* **12**: 199-200.

Abro, G.H., Syed, T.S., Umer, M.I. and Zhang, J. (2004). Effect of application of a growth regulator and micronutrients on insect pest infestation and yield components of cotton. *J. Entomol.,* **1** (1): 12-16.

Abu-Rayyan, A., Nazer, I. and Qudeimat, E. (2004). Effect of some fruit setting induction means on yield and fruit quality of strawberry grown under plastic house in the Jordan Valley. *Dirasat Agri. Sci.,* **31** (3): 296-301.

Adelana, B. O. (1976). Effect of planting date on the growth and yield of tomato in Western Nigeria. *Ghana J. Agric. Sci.,* **10** (1): 11-15.

Alam, M. S., Iqbal, T. M. T., Amin, M. and Gaffar, M. A. (1989). Krishitaltic Fasalcr Utpadan O Unnayan (in Bengali). T. M. Jubair Bin Iqbal, Sirajgonj. pp. 231-239.

Anonymous. (1989). Annual Report (1987-88). Bangladesh Agricultural Research Institute. Joydebpur, Gazipur. p. 133.

Anonymous. (1992). Chinese cabbage or pet-sai In: Vegetable production in the Sub- Tropics and Tropics. Overseas Technical Cooperation Agency, Japan, Text Book, **25**: 146-157.

Aparajita, B. (2002). Effect of seedling age on growth and yield of tomato and brinjal. Department of Nematology, Assam Agricultural University, Jorhat 785013, Assam, India. Pp. 120-130.

AVRDC. (1981). Chinese cabbage. AVRDC. Shanhua, Taiwan. 300p.

Bhat, K.L. and Singh, A.K. (1998). Effect of different levels of phosphorus, NAA and pickings on seed production of okra. *Environment and Ecology.***16** (2); 350-352.

Bose, T. K. and Som, M. G. (1986). Vegetable crops in India. Naya Prokash 206, Bidhan Sarani, Calcutta, India. pp. 167-180.

Cerne, D.S., Riesen, U. and Scharpf, H.C. (2000). Effect of variety and transplanting time of lettuce. *J. Hebei. Agril. Univ.*, **22** (1): 50-54.

Chatterjee, A. and Sukul, N.C. (1995). Use of growth regulators in control of root knot incidences in okra plants. *J. Movopathol. Res.*, **33** (2): 91-97.

Chaurasiy, J., Meena, M. L., Singh, H. D., A. Adarsh and Mishra, P. K. (2014). Effects of GA_3 and NAA on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.) cv. Pride of India. *The Bioscan*., **9** (3): 1139-1141.

Choi, Y. H., Cho, J. L., Rhee, H. C., Park, D. K., Kwon, J. K. and Lee, J. H. (2002). Effect of summer grown seedling quality on growth and yield of tomato. *J. Korean Soc. Hort. Sci.*, **43** (4): 395-398.

Choudhary, S., Shivran, A.C., Lal, B. and Singh, R. (2018). Effect of nitrogen and plant growth regulators on yield and quality of ajwain (*Trachyspermum ammi* L. Sprague). *Int. J. Curr. Microbiol. App. Sci.*, **7**: 5341-5345.

Chowdhury, A.R., Amin, A.K.M., Uddin, K.S. and Haider, J. (1991). Effect of age of seedlings on growth and yield of brinjal. *Annals Bangladesh Agric.*, **1** (1): 55-57.

Chui, H. L., Chang, W. N., Lin, S. L. and Fan, M. J. (1997). Influence of seedling age on tomato (*Lycopersicon esculentum* Mill.) plant growth and early yield. *J. Agril. Res.*, **46** (1): 305-313.

Csizinszky, A. A. and Schuster, D. J. (2005). Response of cabbage to seedling age plant spacing and fertilizer rates. *J. Amer. Soc. Hort. Sci.*, **110** (6): 888-893.

Das, R. and Rabhal, B.K. (1999). Effect of growth regulators on size and quality of cucumber (*Cucumis sativa* L.) in plastic green house during rabi season. *Crop Res. Hisar.,* **18**: 390-396.

Davies, P.J., (1987). Plant hormone and their role in plant growth and development. Martinus Nijhoff Publ. Dordrecht, Netherlands.

Dayan, E., Rylski, I., Goldberg, C. and Gamliel, B. (1978). The influence of planting date and net covering on the yield of three tomato cultivars. *Hassade, Bet Dagan Israel.,* **59** (2): 237-244.

Deb, P., Suresh, C. P., Saha, P. and Das, N. (2009). Effect of NAA and GA_3 on yield and quality of tomato (*Lycopersicon esculentum Mill.*). *Env. and Ecol.,* **27** (3): 1048-1050.

Dharmender, K., Guja, K. D., Paliwal, R. and Kumar, D. (1996). Yield and yield attributes of cabbage as influenced by GA_3 and NAA. *Crop Res. Hisar.,* **12** (l): 120-122.

Dhengle, R. P. and Bhosale, A. M. (2008). Effect of plant growth regulators on yield *(Brassica oleracea* var. *capitata). Int. J. Pl. Sci.,* **3** (2): 376-378.

El- Otmani, M., Coggins, C. W., Agusti, M. and Lovatt, C.J. (2000). Plant growth regulators in citriculture: world current uses. Rev. *Plant Sci.,* **19**: 395-447.

Edris, K. M., Islam, A. T. M. T., Chowdhury, M. S. and Maque, A. K. M. M. (1979). Detailed Soil Survey of Bangladesh Agricultural University Farm, Mymensingh, Dept. Soil Survey, Govt. People's Republic of Bangladesh. 118 p.

FAO. (1988). Production Year Book. Food and Agricultural Organization of the United Nations. Rome, Italy. **42**: 190-193.

Gedam, V.M., Patil, R.B., Suiyawanshi, Y.B. and Mate, S.N. (1998). Effect of plant growth regulators and boron on flowering, fruiting and seed yield of bitter gourd. *Seed Res.* **26**: 97-100.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research (2nd edn.). Int. Rice Res. Inst., A Willey Int. Sci., Pub., pp. 28-192.

Guttormsen, G. (1996). The effect of nitrogen fertilization on yield, quality, and storage ability of Chinese cabbage. Norsk-Landbruksforsking. 1996, **10**: 3-4, 189-198.

Harrington, J.F., Rappaport, L. and Hood, K.J. (1996). The influence of gibberellins on stem elongation and flowering on endive. Science. **125**: 601.

Henare, M. and Ravanloo, A. (2008). Effect of transplanting stage and planting depth of seedling on growth and yield of tomato. Book of abstracts. IV Balkan Symposium on *Vegetables and Potatoes. Plovdiv.*, **96**: 43-51.

Holcomb, E.J. (ed.). (1994). Bedding Plants IV. Ball Publishing, Batavia, III.

Iqbal, M., Khan, M. Q., Jalal, U. D., Rehman, K. and Munir M. (2009). Effect of foliar application of NAA on fruit drop, yield and physico-chemical characteristics of guava (*Psidium guajava* L.) Red flesh cultivar. *J. Agric. Res.*, **47**: 259-269.

Islam, M. A., Siddique, A. and Kashem, M. A. (1993). Effect of growth regulators on the growth, yield and ascorbic acid content of cabbage. *Bangladesh J. Agril. Sci.*, **20** (1): 21-27.

Islam, M. S. and Haque, M. A. (1992). Soil and fertilizer management for vegetables. Proceedings of a national review and planning workshop. BARI, Joydebpur, Gazipur, Bangladesh.

Jain Guo Li, Xu Ming H and Hui Bal. (2004). NAA sprays increased litchi fruit size and its roles. *J. South China Agri. Univ.*, **25** (2): 10-12.

Kar, A.K., Islam, M. K., Maniruzzaman, M. and Khatun, K. (2003). Effect of plant growth regulators (PGR) on growth and yield of two cabbage varieties. *Bangladesh J.*, p. 807-811.

Kato, T. (1981). The physiological mechanism of heading in Chinese cabbage. In: Talekar, N. S. and Griggs, T. D. (cds.). Chinese cabbage. AVRDC, Shanhua, Taiwan, China. P. 207-215.

Kler, D. S., Kaur, H. and Sarbjeet, S. (1992). Relationships among light interception, yield contributing characters and yield of Chinese cabbage crop. *Env. and Ecol.,* **10** (4): 896-899.

Kobryn, J. (1987). Effect of sowing date, cultivar and spacing on the yield and quality of Chinese cabbage in autumn-winter greenhouse production. Zeszyty Naukowc Akademii Rolniczej im. IIugona KolIataja-w-Krakowie, Ogrodnictwo. **211** (16), 87-107.

Kumar, D., Gujar, K. D. and Singh, K. (1996). Effect of GA_3 and NAA on growth, chlorophyll content and maturity of cabbage. *Crop Res. (Hisar).* **12** (1): 116-119.

Kuo, C. G. and Tsay, J. S. (1981). Physiological response of Chinese cabbage under high temperature. In: Talekar, N. S. and Griggs, T.D. (cds). Chinese cabbage. Chinese cabbage. AVRDC, Shanhua, Tainan, Taiwan. pp. 217-224.

Laskshmamma, P. and Rao, I. V. S. (1996). Response of blackgram (*Vigna mungo* L.) to shade and naphthalene acetic acid. *Indian J. Plant Physiol.,* **1**(1): 63-64.

Lee, J. W. and Kim, K. Y. (1999). Effects of seedling age and transplanting depth on growth and yield of tomato. *J. Korean Soc. Hort. Sci.,* **40** (4): 412-415.

Leonard, B. R. (1962). Inter-relationship of vegetative and reproductive growth with special reference to intermediate plants. *Bot. Rev.,* **28**: 253-400.

Magnusson, M. (2002). Mineral fertilizers and green mulch in Chinese cabbage [*Brassica pekinensis* (Lour.) Rupr.]: effect on nutrient uptake, yield and internal tipburn. Acta Agricultural Scandinavica. Section-B, *Soil and*

Plant Science., **52**: 1, 25-35.

Mehraj, H., Taufique, T., Ali, M. R., Sikder, R. K. and Jamal Uddin A. F. M. (2015). Impact of GA_3 and NAA on horticultural traits of *Abelmoschus esculentus*. *World Appl. Sci. J.*, **33** (11): 1712-1717.

Moniruzzaman, M., Khatoon, R., Hossain, M. F. B, Jamil, M. K. and Islam, M. N. (2014). Effect of GA_3 and NAA of various plant growth regulators on growth, quality and physiology of *Capsicum annum* L. The *Asian-Australas. J. Plant Sci. and Biotechnol.,* **4** (1): 24-29.

Muthoo, A. K., Kumar, S. and Maurya, A. N. (1987). Studies on the effect of foliar application of GA_3, NAA and molybdenum on growth and yield of cauliflower (*Brassica oleracea* var. *capitata* L.). *Haryana J. Hort. Sci.*, **16** (12): 115-120.

Nkansha, G. O., Ofosu-Anim, J. and Mawuli, A. (2012). Gibberellic acid and naphthalene acetic acid affect fruit retention, yield and quality of keitt mangoes in the coastal savanna ecological zone of Ghana. *J. Plant Physio.*, **7**: 243-251.

Okano, K., Sakamoto, Y. and Watanabe, S. (2000). Effects of seedling age at planting on plant from and fruit productivity of single truss tomato grown hydro phonically. *Ornamental Plants and Tea.,* **15**: 123-134.

Olaiya, C. O., Soetan, K. O. and Ogunkolade, N. S. (2010). Evaluation of the biochemical effects of auxins on nutritional quality of tomato (*Solanum lycopersicum*).

Opena, R.T., Kuo, C. G. and Yoon, J. Y. (1988). General botany and reproductive biology. In. Breeding and Seed Production of Chinese cabbage in Tropics and sub-tropic. AVRDC. Shanhua, Tainan, Taiwan. Pp. 7-17.

Orzolek, M. (2004). Evaluating vegetable transplants. Vegetable, small fruit and specialty crops. *Virginia Cooper. Extn.*, **3** (3): 9-16.

Patel, V.P., Plal, E. and John, S. (2016). Comparative study of the effect of plant growth regulators on growth, yield and physiological attributes of chilli (*Capsicum annum* L.) cv. Kashi Anmol. *Int. J. Farm Sci.,* **6** (1): 199-204.

Patil, A. A., Maniur, S. M. and Nalwadi, U. G. (1987). Effect of GA_3 and NAA on growth and yield of cabbage. *South Indian Hort.*, **35** (5): 393-394.

Pandey, S. N. and Sinha, B. K. (1987). Physiology. Revised edition. Vikash Publishing House Pvt. Ltd., New Delhi- 110014. Pp. 444-445.

Rahrnan, A. K. M. M., Haque, M. and Hossain, S. M. M. (1994). Effect of age of seedlings on the growth and yield of tomato variety Manik. Punjab vegetable grower, **29**:13-14 [Cited from *Hort. Abst,* **66** (5): 4208. 1996].

Rahman, M. and Quasem, A. (1986). Effect of plant spacing and age of seedling on yield of tomato. *Bangladesh Soc. Agron. Annual Conf.,* Pp. 10-11.

Rai, S., Hossain, M. and Hossain, F. (1998). Effect of growth regulators on yield of quality of okra fibre. *Hort J.* **11** (1): 77-82.

Rajbir, S., Ram-Asrey and Satyendra, K. (2005). Effect of transplanting time and mulching on growth and yield of tomato. *Indian J. Hort.*, **62** (4): 350-353.

Rashid, M. M. (1999). Sabjii Biggan. Rashid Publishing. House, 94. Old DOHS. Dhaka-1206. p. 248.

Ravikumar, R. and Shanmugavelu, K. G. (1983). Studies on the effect of different methods and time of sowing on yield and quality of certain varieties of tomato. In proceedings of national seminar on production technology of Tomato, Comibatore, India. Pp. 57-68.

Sanjoy Saha. (1999). Impact of seedling age and planting time on yield performance of tomato (*Solanum lycopersicum*) in upland rice (*Oryza* *sativa*) based cropping system. *Indian J. Agron.,* **44** (4): 669-672.

Santipracha, Q. and Sadoodee, S. (1995). Cabbage grown in the rainy season under different rain protectors in Songkhla. *Thailand Agril.,* **23** (2): 74-80.

Sarker, R., Ray, S. P., Paul, J., Nusrat, A and Tithi, M. J. (2017). Effect of seedling age on growth and yield of Tomato. *Intl. J. Agril.,* **2** (2): 13-17.

Sayed, A., Hussain, S.A., Nawab, A., Asghar, S. and Ali, N. (1997). Effect of exogenous growth regulators on growth, flowering and yield of okra. *Sarhad J. Agril.,* **13** (5): 449-453.

Sharma, K. C. (2001). Response of fertility and spacing to seed production of Chinese cabbage (*Brassica campestris* subsp. *pekinensis*) under north-western Himalayas. *Indian- J. Agril. -Sci.,* **71** (9): 608-609.

Shoemaker, J. S. (1947). Vegetable growing. New York, John Wiley and Sons. Inc. p. 506.

Singh, K. N., Khan, G. M. and Bali, A. S. (2001). Response of *Brassica campestris* to residual effect of organic manure, nitrogen and transplanting dates of rice. *Indian- Journal-of-Agronomy.,* **46** (3): 395-399.

Singh, N., Biswas, T. K. and Sharma, R. (2014). Impact of plant growth regulators on vegetative characters, quality and yield attributes in chilli (*Capsicum annum* L.) cv. G-4. *New Agric.,* **25** (2):227-233.

Singh, D. K., Rudra, B. C., DAS, B. and Gangopadhyay, P. K. (2015). Effect of naphthalene acetic acid on yield of chilli (*Capsicum annum* L.). *J. Agric. Technol.,* **2** (1&2): 84-86.

Sitadhani, K. and Bosnyake, J. K. (1988). Effect of manure on growth and yield of Chinese cabbage. In: Training report. AVRDC-TOP, Bangkok, Thailand, pp. 55-59.

Souma, S., Hirai, L. and Wabuchi, H. (1976). i) The effect of environment on the growth and quality of tomato. ii) Effect of the length of the seedling stage on the growth, yield and quality of tomatoes. *Bulletin Hokkaido*

Protectoral Agril. Expt. Staliomons. **34**: 32-40. [Cited from Hort. Abst., **47** (10): 9472, 1977].

Sridhar, G., Koti, R. V., Chetti, M. B. and Hiremath, S. M. (2009). Effect of naphthalene acetic acid and mepiquat chloride on physiological components of yield in bell pepper (*Capsicum annuum* L.). *J. Agric. Res.,* **47** (1): 53-62.

Staugaitis, G. and Viskelis, P. (2005). Amounts of nitrogen, phosphorus, potassium, calcium and magnesium in the heads and plant residues of Chinese cabbage crop fertilized with different rates of nitrogen. Sodininkyste-ir-Darzininkyste., **24** (1): 98-106.

Talekar, N. S. and Griggs, T. D. (1981). Chinese cabbage. AVRDC, Taiwan, China.

Talekar, N. S. and Selleck, G. W. (1982). Fareward. In: Talekar, N. S. and Griggs, T. D. (cds.). Chinese cabbage. AVRDC, Shanhua, Taiwan, China.

Tanaka, T., Hotta, Y. and Ito Kazuhisa. (1998). Effects of seedling age of scions grafted in eggplant plug seedlings on the growth and yield of eggplant. *Res. Bull. of the Aichi-ken Agric. Res. Center.,* **30**: 131-138.

Tapdiya, G. H., Gawande, P. P., Ulemale, P. H., Patil, R. K. and Naware, M. S. (2018). Effect of growth regulators on quantitative characters of chilli (*Capsicum annuum* L.). *Int. J. Curr. Microbiol. App. Sci.,* **6**: 2151-2157.

Thapa, U., Das, R., Mandal, A. R. and Debanath, S. (2013). Influence of GA_3 and NAA on growth, yield and quality attributing characters of sprouting broccoli (*Brassica oleracea* var. *italica* L.) *Crop Res.,* **46** (1, 2&3): 192-195.

Thompson, H. C. and Kelly, W. C. (1957). Vegetable crops. 5th Edn. McGraw Hill Book Co., New York. p. 392.

Thonguthaisri T. (1984). Problem of Chinese cabbage growing and seed production. In: Talekar, N. S. and Griggs, T. D. (cds). Pp. 78- 142.

Thy, S. Buntha, P. (2005). Evaluation of fertilizer of fresh solid manure, composted manure or biodigester effluent for growing Chinese cabbage (*Brassica pekinensis*). Livestock-Research-for-Rural-Development.; **17** (3): 26.

UNDP. (1988). Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2: Agroecological Regions of Bangladesh, FAO, Rome. pp. 212, 577.

Vavrina, C. S. (1998). Transplant age in vegetable crops. *Hort. Tech.,* **8** (4): 550–555.

Vejenda, P. and Smith, R. L. (2008). Effect of chemicals and growth regulators on fruit retation, yield and quality of mango cv. Amrapali. *Sci. Hort.,* **54**: 211-219.

Vijoy, K. N. R. and Kumar, V. (2000). Effect of plant growth regulators on cauliflower cv. Plant subhra. *Orisa J. Hort.,* **28** (1): 65-67.

Wang, Z. and Li, S. (2004). Effects of nitrogen and phosphorus fertilization on plant growth and nitrate accumulation in vegetables. *J. Plant Nutri.,* **27** (3): 539-556.

Williams, R. R. and Taji, A. M. (1989). Auxin type, gel concentration, rooting and survival of Cheirantheravolubilis *In vitro. J. American. Soc. Hort. Sci.,* **24**: 305-307.

Yadav, R. L., Dhaka, R. S. and Fageria, M. S. (2000). Effect of GA_3, NAA and succinic acid on growth and yield of cabbage cv. golden acre. *Haryana J. Hort. Sci*., **29** (3/4): 269-270.

Zhao Rui. and Chen, J. Q. (2004). Study on age and nutritive area of tomato seedlings grown in plug tray. *China Veg.,* **4**: 19-21.

APPENDICES

Appendix I. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October 2019 to January 2020

Month	Air temperature (°C)			Average RH (%)	Total rainfall (mm)
	Maximum	Minimum	Mean		
October 06	31.25	21.55	24.40	78.55	28.55
November 06	29.18	18.26	23.72	69.52	00
December 06	25.82	16.04	20.93	70.61	00
January 07	24.22	14.42	19.32	78.50	00

Appendix II. Results of mechanical and chemical analysis of soil of the experimental plot

Mechanical analysis

Constituents	Percent
Sand	32.45
Silt	61.35
Clay	6.10
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.15
Organic carbon (%)	1.32
Total nitrogen (%)	0.075
Available P (ppm)	19.5
Exchangeable K (%)	0.2

Appendix III. Analysis of variance of the data on plant height of Chinese cabbage as influenced by seedling age and NAA

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		20 DAT	35 DAT	50 DAT	Harvest
Replication	2	2.331	2.410	2.482	3.253
Seedling age (A)	2	8.968**	11.994**	15.484**	15.733**
NAA (B)	3	4.009**	5.411**	6.240**	7.582**
Interaction (AXB)	6	1.709*	2.156**	2.717**	2.790**
Error	22	0.505	0.528	0.521	0.519

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IV. Analysis of variance of the data on plant spread of Chinese cabbage as influenced by seedling age and NAA

Source of variation	Degrees of freedom	Mean square			
		Plant spread (cm) at			
		20 DAT	35 DAT	50 DAT	Harvest
Replication	2	1.281	2.144	2.480	0.442
Seedling age (A)	2	24.493**	9.243**	9.042**	9.527**
NAA (B)	3	13.017**	4.218**	3.898**	3.439**
Interaction (AXB)	6	0.553*	1.806**	1.699*	3.529**
Error	22	0.209	0.517	0.526	0.782

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on number of unfolded leaves of Chinese cabbage as influenced by seedling age and NAA

Source of variation	Degrees of freedom	Mean square			
		Number of unfolded leaves at			
		20 DAT	35 DAT	50 DAT	Harvest
Replication	2	0.093	0.082	0.085	0.028
Seedling age (A)	2	9.926**	7.203**	9.790**	11.001**
NAA (B)	3	1.893**	6.168**	1.898**	1.939*
Interaction (AXB)	6	1.797**	1.238*	1.853**	1.485*
Error	22	0.242	0.449	0.259	0.505

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VI. Analysis of variance of the data on number of folded leaves of Chinese cabbage as influenced by seedling age and NAA

Source of variation	Degrees of freedom	Mean square			
		Number of folded leaves at			
		20 DAT	35 DAT	50 DAT	Harvest
Replication	2	0.272	0.297	0.258	0.039
Seedling age (A)	2	9.883**	9.738**	9.794**	10.995**
NAA (B)	3	4.032**	4.064**	4.185**	1.973*
Interaction (AXB)	6	0.681*	0.693*	0.704*	1.477*
Error	22	0.268	0.250	0.252	0.504

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VII. Analysis of variance of the data on root and stem characteristics of Chinese cabbage as influenced by seedling age and NAA

Source of variation	Degrees of freedom	Mean square			
		Number of roots per plant	Length of roots(cm)	Length of stem (cm)	Diameter of stem (cm)
Replication	2	0.017	0.028	0.041	0.0002
Seedling age (A)	2	11.164**	10.522**	0.496**	0.673**
NAA (B)	3	1.981*	1.909*	0.132**	0.171**
Interaction (AXB)	6	1.484*	1.485*	0.026**	0.055**
Error	22	0.505	0.497	0.003	0.003

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of the data on yield contributing characters of Chinese cabbage as influenced by seedling age and NAA

Source of variation	Degrees of freedom	Mean square				
		Days from transplanting to initiation of head	Days from transplanting to head maturity	Diameter of head (cm)	Thickness of head (cm)	Fresh weight of unfolded leaves per plant (g)
Replication	2	0.053	0.002	0.023	0.001	0.670
Seedling age (A)	2	6.909**	28.361**	1.211**	1.769**	13.686**
NAA (B)	3	3.998**	6.726**	11.228**	13.386**	1.365**
Interaction (AXB)	6	21.609**	25.985**	0.078**	0.051**	1.002**
Error	22	0.022	0.003	0.017	0.001	0.217

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IX. Analysis of variance of the data on yield contributing characters of Chinese cabbage as influenced by seedling age and NAA

Source of variation	Degrees of freedom	Mean square				
		Fresh weight of head per plant (kg)	**Fresh weight of total plant (kg)**	**Dry matter contentof head(%)**	**Gross Yield (kg/plot)**	**Gross Yield (t/ha)**
Replication	2	0.004	0.001	0.071	0.051	0.901
Seedling age (A)	2	0.248**	0.085**	5.902**	3.056**	53.959**
NAA (B)	3	0.088**	0.064**	1.621**	2.294**	40.530**
Interaction (AXB)	6	0.009**	0.040**	1.935**	1.437**	25.389**
Error	22	0.002	0.005	0.156	0.188	3.321

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix X. Production cost of Chinese cabbage per hectare

i. **Input cost**

Treatment combination	Labour cost	Ploughing cost	Seed cost	Water for seedlings establishment	NAA cost	Manure and fertilizers				Insecticide /pesticides	Sub-total (A)
						Cowdung	Urea	TSP	MOP		
A_1N_0	50,000	30,000	14,000	25,000	0	20,000	5,000	6,000	4,500	15,000	169,500
A_1N_1	50,000	30,000	14,000	25,000	5,000	20,000	5,000	6,000	4,500	15,000	174,500
A_1N_2	50,000	30,000	14,000	25,000	7,500	20,000	5,000	6,000	4,500	15,000	177,000
A_1N_3	50,000	30,000	14,000	25,000	10,000	20,000	5,000	6,000	4,500	15,000	179,500
A_2N_0	50,000	30,000	14,000	25,000	0	20,000	5,000	6,000	4,500	15,000	169,500
A_2N_1	50,000	30,000	14,000	25,000	5,000	20,000	5,000	6,000	4,500	15,000	174,500
A_2N_2	50,000	30,000	14,000	25,000	7,500	20,000	5,000	6,000	4,500	15,000	177,000
A_2N_3	50,000	30,000	14,000	25,000	10,000	20,000	5,000	6,000	4,500	15,000	179,500
A_3N_0	50,000	30,000	14,000	25,000	0	20,000	5,000	6,000	4,500	15,000	169,500
A_3N_1	50,000	30,000	14,000	25,000	5,000	20,000	5,000	6,000	4,500	15,000	174,500
A_3N_2	50,000	30,000	14,000	25,000	7,500	20,000	5,000	6,000	4,500	15,000	177,000
A_3N_3	50,000	30,000	14,000	25,000	10,000	20,000	5,000	6,000	4,500	15,000	179,500

B. Overhead cost

Treatment combination	Cost of lease of land (Tk.13% of value of land cost/year)	Miscellaneous cost (Tk. 5% of the input cost)	Intereston running capital for 6 months (Tk. 13% of cost/year)	Sub- total (Tk.) (B)	Total cost of production (Tk./ha) [Input cost (A) + overhead cost (B)]
A_1N_0	78,000	8,116	15,225	101,341	270,841
A_1N_1	78,000	8,440	15,316	101,756	276,256
A_1N_2	78,000	8,515	15,331	101,846	278,846
A_1N_3	78,000	8,590	15,345	101,935	281,435
A_2N_0	78,000	8,116	15,225	101,341	270,841
A_2N_1	78,000	8,440	15,316	101,756	276,256
A_2N_2	78,000	8,515	15,331	101,846	278,846
A_2N_3	78,000	8,590	15,345	101,935	281,435
A_3N_0	78,000	8,116	15,225	57,759	270,841
A_3N_1	78,000	8,440	15,316	58,377	276,256
A_3N_2	78,000	8,515	15,331	58,562	278,846
A_3N_3	78,000	8,590	15,345	58,747	281,435

A_1: 15 days of seedling
A_2: 25 days of seedling
A_3: 35 days of seedling

N_0: 0 ppm (control)
N_1: 40 ppm of NAA
N_2: 80 ppm of NAA
N_3: 120 ppm of NAA

Appendix XI: Photographs of the experiment

Plate 1: Photograph showing experimental plot

Plate 2: Photograph showing Chinese cabbage after harvesting