EFFECT OF NITROGEN AND MULCHING ON THE GROWTH AND YIELD OF CHINESE CABBAGE (*Brassica campestris var. Pekinensis)*

BY

DILRUBA EASMIN
REGISTRATION NO. 00507/26216

A Thesis

Submitted to the Department of Horticulture & Postharvest Technology
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN
HORTICULTURE AND POSTHARVEST TECHNOLOGY
SEMESTER: JULY-DECEMBER, 2006

APPROVED BY:

Md. Hasanuzzaman Akand
Assistant Professor
Department of Horticulture and Postharvest Technology
Sher-e-Bangla Agricultural University, Dhaka
Supervisor

Dr. Md. Nazrul Islam
Associate professor
Department of Horticulture and Postharvest Technology
Sher-e-Bangla Agricultural University, Dhaka
Co-Supervisor

Prof. Md. Ruhul Amin
Chairman
Examination Committee
Department of Horticulture and Postharvest Technology
Sher-e-Bangla Agricultural University

December 2006

CERTIFICATE

This is to certify that the thesis entitled **"Effect of Nitrogen and Mulching on the Growth and Yield of Chinese Cabbage** (*Brassica campestris* var. pekinensis)" 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 IN HORTICULTURE AND POSTHARVEST TECHNOLOGY, embodies the result of a piece of bona fide research work carried out by **DILRUBA EASMIN**, Registration No. **00507/26216** 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:

Dhaka, Bangladesh

Supervisor
Md. Hasanuzzaman Akand
Assistant Professor
Department of Horticulture
and Postharvest Technology
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1205

DEDICATED
TO
MY BELOVED PARENTS

ACKNOWLEDGEMENTS

The auther express her sincre gratitude to Almighty Allah for His everending blessings for the successful completion of the research work.

The author feels proud to express her deepest respect, sincere appreciation and immense indebtedness to her Supervisor Md. Hasanuzzaman Akand, Assistant Professor, Department of Horticulture and Postharvest Technology, Sher-e-Bangla Agricultural University, Dhaka, for his continuous guidance, constructive criticism and valuable suggestions in carrying out the research work and preparation of this thesis.

The author also expresses her gratitude and best regards to her respected Co-Supervisor, Dr. Md. Nazrul Islam, Associate Professor, Department of Horticulture and Postharvest Technology, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, helpful comments and constant inspiration throughout the research work and preparation of the thesis.

The author expresses her sincere respect to Professor Md. Ruhul Amin, Chairman, Department of Horticulture and Postharvest Technology, 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 and Postharvest Technology, SAU, for their valuable suggestions and encouragement during the period of the study.

The auther is very thankful to Nirmal Das, Coordinator (Research), WAVE Foundation, Dhaka for analysing the data and helpful suggestion for preparion of this manuscript.

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

The Author

EFFECT OF NITROGEN AND MULCHING ON THE GROWTH AND YIELD OF CHINESE CABBAGE (*Brassica campestris* var. pekinensis)

By

DILRUBA EASMIN

ABSTRACT

An experiment was conducted in the Horticulture Farm of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2005 to December 2005 to study the effect of different levels of Nitrogen and mulching on the growth and yield of Chinese cabbage. The experiment considered of two factors. Factor A: Levels of nitrogen (4 levels) i.e. N_0 (No N fertilizer/Control), N_1 (160 kg/ha), N_2 (200 kg/ha) and N_3 (250 kg/ha); Factor B: Mulches (4 levels) i.e. M_0 (No mulch), M_1 (black polythene), M_2 (saw dust) and M_3 (water hyacinth). There were on the whole 16 (4 × 4) treatments combinations. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Data were collected in terms of yield contributing characters and yield of Chinese cabbage. A significant variation was recorded in respect of all of the recorded characters in relation with different levels of nitrogen. The tallest Chinese cabbage plant during harvest was recorded from N_3. The longest duration to start head formation from seed sowing were recorded from N_0 and the longest duration of head maturity from initiation was recorded from N_0. The maximum thickness and diameter of head were recorded from N_3. The highest marketable yield was recorded from N_3. The highest plant height during harvesting period was recorded from M_1. The longest duration to start of head formation from seed sowing and the longest duration of head maturity from initiation were recorded from M_0. The maximum thickness and diameter of head were recorded from M_1. The highest marketable yield were recorded from M_1. Interaction effect between different levels of nitrogen and mulches confirmed no significant differences. In every case maximum growth and yield contributing characters and yield was observed from N_3M_1. In the combination of different doses of nitrogen and different mulches highest benefit cost ratio was attained from the treatment combination of N_3M_1.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter I

INTRODUCTION

Chapter I

INTRODUCTION

Chinese cabbage (*Brassica campestris* var. pekinensis) is an important leafy, herbaceous vegetable crop originated in China and belonging to the family Cruciferae (Rashid, 1999). From China it was extended towards Japan, Korea, Taiwan and Indonesia. It is also a well known and widely distributed crop within Asia and has been introduced successfully into parts of Central America, West Africa, America, Canada and Europe (Talekar and Selleck, 1982). It is a short duration crop and grown for its compact head.

In Bangladesh Chinese cabbage is not well known and is being grown on a very limited scale due to the lack of awareness regarding its consumption practices and appropriate method of production technology. But in recent years, a good deal of interest has generated among the farmers for raising this crop extensively. At that time consumption utility and interest increasing day by day to the common people in our country.

To attaining considerable production and quality yield for any crop it is necessary to proper management including ensuring the availability of essential nutrient components. Chinese cabbage thrives well in a fertile, clay loam soil because it requires considerable amounts of nutrients to sustain rapid growth in short time. A large amount of nitrogen is required for the growth of the non-heading leaves and the differentiation of inner head leaves (Opena *et al.*, 1988). Nitrogen has profound effect on the number of folded leaves and progressively increases the marketable yield (Obreza and Vavrina, 1993). Nitrogen had the largest effect on yield and quality of Chinese cabbage (Liu *et al.*, 1999). A shortage of nitrogen during early growth may lead to the condition known as "buttoning" when plant becomes stunted with reduced leaf development (Tindall, 1983).

Nitrogen plays a vital role as a constituent of protein, nucleic acid and chlorophyll. It is also the most different element to manage in a fertilization system such that an adequate, but not excessive amount of nitrogen is available during the entire growing season (Anon., 1972). An adequate supply of nitrogen is essential for vegetative growth, head formation and desirable yield (Yoshizawa *et al.*, 1981). On the other hand excessive application of nitrogen is not only uneconomical, but it can prolong the growing period and delay crop maturity. Excessive nitrogen application causes physiological disorder that appears small black spots on the midribs of head leaves (Obreza and Vavrina, 1993).

In Bangladesh, Chinese cabbage is grown during winter season where rainfall is scanty but it needs plenty of moisture of soil for its normal growth and development. Mulching play an important role to reduce the evaporation loss of soil and in this way, it maintains sufficient moisture in the soil. On the other hand, Chinese cabbage is a cool seasonal herbaceous leafy crop and it favors temperature range from 15-20^{0}C. If the temperature exceeds 25^{0}C, this crop can not form compact head. Mulching also provide acceptable temperature to the soil by protecting sunlight. In most of the time, irrigation expenses increase the cost of production resulting in unprofitable production of Chinese cabbage and make growers frustrated.

Any practices that act as a barrier to the evaporation of water or heat from soil surface can be defined as mulching. There are two types of mulching practices viz., natural mulching; breaking the upper crust of soil to disconnects the capillary pore for checking evaporation and artificial mulching; covering the soil surface with plant species, crop residues or polythene sheet. The benefit of mulching also includes regulation of soil moisture, temperature and suppressing weeds resulting in higher yield and quality of Chinese cabbage.

Mulching offers tremendous potential for increased crop production through its noticeable effect on the soil environment which ensures proper growth and yield of crop (Lal, 1989).

The efficient use of nitrogen from the economic point of view can be achieved by soil moisture management through mulching. Mulching may be practical in crop cultivation which can minimize cost of production. The efficiency of nitrogen fertilizer use was normally 30% under Bangladesh context, which was increased upto 53% with special arrangement through mulching (Sweeney *et al.*, 1987). Combined effect of nitrogen and mulching has also increasing growth and yield of Chinese cabbage (Russo *et al.*, 1997).

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

1. To identify the optimum dose of nitrogen for growth and development of Chinese cabbage.
2. To identify the effect of mulching and suitable mulching material in consideration of growth, yield as well as maximum return.
3. To measure the combined effect of different levels of nitrogen and mulches for attaining maximum yield in Chinese cabbage.

Chapter ii

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

Chinese cabbage is one of the leafy vegetable crops of Bangladesh and as well as many countries of the world. The crop has received much attention by the researchers on various aspects of its production and utilization for different consumer uses in the very recent. Very few studies on the related to growth, yield and development of Chinese cabbage have been carried out in many countries of the world. The work so far done in Bangladesh and is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings so far been done at home and abroad on this aspect on the cruciferae family have been reviewed in this chapter under the following headings –

2.1 Effect of nitrogen

To examine the effect of organic amendment application on the fate of inorganic-N accumulated in a vegetable field soil during conversion from inorganic to organic input, a pot experiment using 15N-labeled soil was conducted by Choi *et al.* (2004) and the soil was labeled with 15N through addition of urea-15N (98 atom % 15N) and was then incubated for 1 year resulting in inorganic soil-N concentration and 15N abundance of 211 mg kg-1 soil and 4.950 atom %, respectively. Chinese cabbage plants were grown in the labeled soil for 30 and 60 days after application of organic amendment at the rates of 0 (control), 200, 400, and 600 mg N kg-1 soil. Although organic amendment application did not show any significant effect on the uptake efficiency of inorganic-N by Chinese cabbage during the first 30 days, it significantly increased inorganic-N uptake efficiency as well as total-N uptake and dry matter yield at the end of the 60-day growth period.

Ye *et al.* (2004) conducted a field experiments in China to study the effects of the combined application of organic manure and chemical fertilizer on the yield and quality of Chinese cabbage. The combined application of organic manure and fertilizer improved the yield and quality of Chinese cabbage. Greater yield and quality were obtained when organic manure was applied at 3750 kg/667 m^2 and when the chemical fertilizer was applied at 30 kg/667 m^2.

A survey on current fertilizer practices and their effects on soil fertility and soil salinity were conducted by Chen *et al.* (2004) from 1996 to 2000 in Beijing Province, a major vegetable production area in the North China Plain. Inputs of the major nutrients (NPK) and fertilizer application methods and sources for different vegetable species and field conditions were evaluated. Excessive N and P fertilizer application, often up to about 5 times the crop requirement in the case of N, was very common, especially for high-value crops.

Jaenaksorn and Ikeda (2004) in an attempt to reduce the hydroponic growing cost and to ease the preparation and source of nutrient solution, soil fertilizer was evaluated as a substitute for soilless nutrient solution in Osaka Prefecture, Japan in 1999. Satisfactory results were achieved in all vegetables tested. However, the growth in soilless solution was significantly better than in soil fertilizer solution.

A plot experiment was conducted by Qian *et al.* (2003) China, to determine the effects of IFC-microelement fertilizer on the yield of Chinese cabbage. The plots in the experiment all received the same rates of phosphorus and potassium but different rate of nitrogen, combined with or without additional IFC-microelement fertilizer (30 kg h/m-2). The application of IFC-microelement fertilizer at an appropriate rate increased the yield of the crop.

Zhang *et al.* (2004) conducted an experiment to found the effects of organic-inorganic compound fertilizers and inorganic nitrogen fertilizers on the quality and yields of Chinese cabbage cv. Luxing. The results show that application of organic-inorganic compound fertilizer produced the highest yield among all treatments; the yield was higher by 14.4, 6.3, 10.6, 4.6 and 33.6% compared with the treatments of ammonium nitrate, ammonium sulfate, urea, organic-inorganic compound fertilizer and the control, respectively. Among the three inorganic nitrogen fertilizers, the treatment of ammonium sulfate resulted in the highest yield. No significant difference in nitrate content of Chinese cabbage was observed between the treatments with nitrogen fertilizers of different N forms.

Krezel and Koota (2004) conducted an experiment to determine the effects of N fertilizer rate (50, 100, 150, 100 + 50, 200 and 100 + 50 + 50 kg/ha) on the yield and nitrate, dry matter, sugar and vitamin C content of Chinese cabbage were determined in a field experiment conducted in Poland during the autumn of 1999-2002. Application of 100 + 50 kg N/ha resulted in the highest total and marketable yield, and dry matter content of the crop. The total and reducing sugar content decreased, whereas nitrate content increased with increasing rates of N.

Warner *et al*. (2004) conduced a field study at the Greenhouse and Processing Crops Research Centre in Ontario, Canada were conducted over 3 years (1999 to 2001) to determine the effects of nitrogen (N) source and rate on petiole spotting (gomasho) and yield of Chinese cabbage. Using 'Kasumi' as the test cultivar and 3 N fertilizer sources (ammonium nitrate, urea and calcium nitrate) were evaluated at 60, 110, 160 and 210 kg N/ha in 1999 and at 100, 200 and 300 kg N/ha in 2000 and 2001 with a zero N rate each year as control. Results indicated that both source and rate of N fertilizer affected the incidence of petiole spotting depending on year was very susceptible to both petiole spotting.

Chen *et al*. (2004) carried out an experiment to investigate the advanced nitrogen (N) advisory systems require target values of N supply for the crop. Two field experiments with different N supply levels were conducted in the Beijing region to determine the target values of N supply and N mineralization rates for optimization of N fertilization of Chinese cabbage (Brassica campestris L. ssp. Pekinensis). Crop yield, N uptake, and soil inorganic N was investigated during the crop growth periods. Marketable yields of the crop increased significantly with N application rate, The agronomically effective N supply levels for Chinese cabbage growth in Beijing region were 349 and 277 kg N ha^{-1}, respectively, for target marketable yields of 120 t FW ha^{-1} for Chinese cabbage.

The effects of nitrogen rates (20, 30, 40 and 60 kg N/10a) on the nitrate contents of cabbages and Chinese cabbages were investigated in Japan by Hatano *et al.* (2003). The nitrate contents of cabbage and Chinese cabbage treated with 30 kg N/10a were 1.26 and 0.75 g NO3/kg FW, respectively. The fresh weights and the nitrate contents of Chinese cabbage increased with increasing nitrogen rate. Although treatment with 60 kg N/10a did not increase the fresh weights, nitrate content in plants were increased.

Wang *et al.* (2003) carried out an experiment on the effects of N rates (0, 75, 150, 225 and 300 kg/ha), soil fertility (low or medium), harvesting date (5, 10, 15, 20, 25, 30, 35, 40 and 45 days) and natural lighting on the biomass, nitrate accumulation and nutritive quality of Chinese cabbage were determined in a field experiment conducted in China. Crop yield increased with increasing rates of N up to 225 kg/ha, whereas nitrate content increased with increasing rates of N regardless of soil fertility levels. Nitrogen application reduced the vitamin C content of the crop under both soil fertility levels, and the soluble sugar and amino acid content of the crop under low fertility. Vitamin C, soluble sugar and amino acid content increased with the delay in harvesting.

The effects of N fertilizers on the yield, vitamin C content and nutrient uptake in Chinese cabbage cv. Parkin were studied in a pot experiment by Ducsay and Varga (2003). The treatments consisted of a control (no fertilizer), and application of 80% N before sowing + 20% N at the onset of head formation, with N as DAM-390, NH_4NO_3, $(NH_4)_2SO_4$, KNO_3 or $Mg(NO_3)_2$. For all the treatments, 100% of P and K were applied before sowing. N, P and K were applied at 40 mg/kg soil, 35 kg/ha, and 175 kg/ha, respectively. All the treatments significantly increased head yield and vitamin C content, and nutrient uptake by plants compared with the control.

An experiment with 3 factors, 4 levels, and 14 treatments was carried out by Liu *et al.* (1999) in 1997 to study the effect of different ratios of NPK combination on yield and nitrate accumulation of Chinese cabbage (Brassica pekinensis). The levels of N were 0, 180, 360, and 540 kg/ha; the levels of P_2O_5 were 0, 90, 180, 270 kg/ha; the levels of K_2O were 0, 90, 180, 270 kg/ha. The plant density of Chinese cabbage was 31thin500/ha. The results showed that the best results were obtained with N360 + P90 + K180. The nitrate accumulation was increased with the increase of the amount of N applied. Phosphate fertilizer had no significant effect on nitrate accumulation in plant; however, potassium fertilizer had a significant effect on nitrate content in plant. Thirty and 50 days after planting were two key periods for fertilizer application on Chinese cabbage.

2.2 Effect of mulching

Kalisz and Cebula (2001) conducted an experiment in Poland to conclude the effect of soil mulched with polythene film and plant covered with non-woven polypropylene and perforated polythene film on the growth and yield of four cultivars of Chinese cabbage (Akala F_1, Optico F_1, Sumiko F_1 and Parkin F_1) during the period 1997-98. Plants coverings were given directly after planting the transplants. Soil mulching was spread 1-2 days before the beginning of the field experiment. They observed that plant height, rosette diameter and the number of leaves and their area build-up by the application of plastic covers considerably improved plant growth. Among the treatments, non-woven polypropylene recorded the highest (90.38 and 60.74 t/ha in 1997 and 1998, respectively) and the control treatment recorded the lowest yields (28.80 and 26.37 t/ha).

Akand (2003) conducted an experiment with organic manure and mulching trail on carrot in Horticulture Farm, BAU, Mymensingh and observed that black polythene and cowdung significantly resulted the highest yield of carrot of his experiment.

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

In an experiment on the effect of mulches (black paper, black polythene, straw) on leeberg, lettuce, bulterhead lettuce, Chinese cabbage and leeks in the Netherlands, Poll and Gaven (1996) observed that mulches increased yields of Iceberg and bulterhead lettuces and Chinese cabbage. Nitrogen leaching to ground water was decreased with mulches.

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

Santipracha and Sadoodee (1995) carried out an experiment in Panjab Agricultural University, India during September, 1992 to January 1993 to study the effect of plastic sheets or nylon net on cabbage and reported that cabbage grown under rain protection showed better growth than control cabbage. The highest head weight (913.5 g) and yield (11.39 t/ha) were observed for cabbages grown under plastic sheets. Rahman (1995) reported similar results for black polythene mulching on cauliflower while conducting an experiment in Bangladesh Agricultural Research Institute, Gazipur, Bangladesh, adding that paddy husk had been found to be more effective in increasing the growth and yield of Cauliflower which straw mulch had adverse effects.

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

Roy *et al.* (1990) carried out an experiment in the department of Crop Botany, Bangladesh Agricultural University, Mymensingh to study the effect of water hyacinth, rice straw and sawdust mulches on the growth of cabbage. They reported that mulches increased crop growth rate, net assimilation rate and leaf area index. Water hyacinth significantly increased chlorophyll-b content, growth and yield.

An investigation was conducted by Benoit and Ceustermans (1990) to estimate the influence of mulch in National Vegetable Research Station, UK on cabbage and found that the yield was better at double layer than that of single layer mulch. It was recorded that double layer of paper mulch had better temperature condition for the growth of the twenty outer leaves than single layer.

Gattorsen (1992) conducted an experiment to evaluate the effects of plastic mulch on the yield of Chinese cabbage and reported that the double layer produced the higher yield than single layer mulching.

Subhan (1989) carried out an experiment with mulching on cabbage in Indonesian Institute of Horticulture, Indonesia and found that mulching increased significantly the head weight and yield of cabbage. Gunadi and Asandhi (1989) while working in Vegetable Research Institute, Seoul, Korea Republic, noticed that straw and plastic mulches encouraged growth of early season Chinese cabbage.

In an experiment conducted by Yoon *et al.* (1984) to study the effect of mulches on cabbage in Vegetable Research Institute, Seoul, Korea Republic and found that black polythene, straw and clear polythene gave higher rate of growth and development of cabbage.

Oh *et al.* (1984) while conducting an experiment in Seoul, Korea Republic, to investigate the effect of different mulches on growth of Chinese cabbage and they found that black polythene mulch increased the growth of cabbage and ensure the optimum soil temperature for proper growth and development as well as higher yield.

Braggnolo and Miclniezuk (1990) also reported that mulches increased the growth and yield of cabbage and as well as marketable yield. Similar results also reported by Ashworth Harrison (1983) conducted an experiment with mulches on cabbage in the Department of Botany, University of Edinburgh, UK and found that mulching increased the marketable yield of cabbage.

An experiment was carried out by Hill *et al.* (1982) in Connecticut Agricultural Experiment Station, New Haven, USA to study the effect of mulches on the growth and yield of cabbage. They found that temperature and moisture regimes of soil were greatly influenced by mulching. They also stated that mulching influenced the growth of cabbage producing well developed root system, highest plat height, spread of plant, stem length, number of loose leaves and diameter of head.

While conducting an experiment in Behar Agricultural College, India, Acharya (1988) and reported that mulching significantly increased the yield of cabbage. Similar results were also found by Oyabu *et al.* (1988) when carried out an experiment in Indonesian Institute of Horticulture, Indonesia.

2.3 Effect of fertilizer and mulches

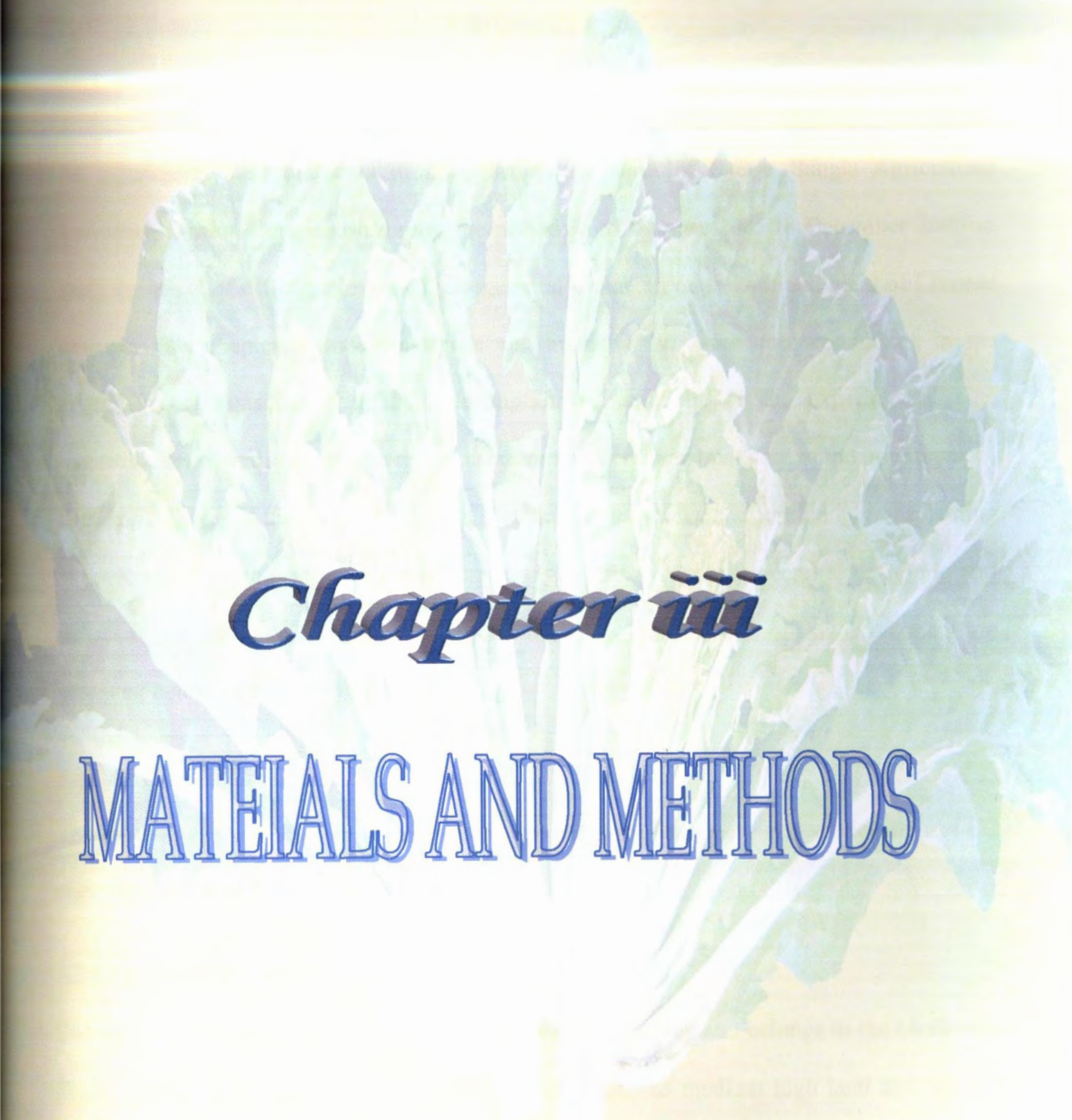
In a trials between Aug. and Nov. by Subhan (1989) at a site 1250 m a.s.l., mulched and unmulched plants received the NPK fertilizer at 0, 600, 800 or 1000 kg/ha. There was no interaction between the fertilizer and mulching with regard to plant growth and yield. Mulching had a significant positive effect on plant height but had little effect on head diameter and yield. The yield was greatest with the highest NPK rate.

Widjajanto *et al.* (2003) conducted an experiment to find out the effects of 0, 20, 40 or 60 g water hyacinth (WH; E. crassipes) residues as source of nitrogen, on the performance Chinese cabbage were determined in a pot experiments conducted in Japan. Dry matter and yield of Chinese cabbage increased with increasing rates of WH residues up to 20 and 40 g, respectively, and decreased thereafter. The height Chinese cabbage radish increased with increasing WH residues up to 20 and 40 g, and decreased thereafter. Application of WH residues reduced the N recovery in Chinese cabbage.

Magnusson (2002) conducted an experiment on mineral fertilizers and green mulch in Chinese cabbage [Brassica pekinensis (Lour.) Rupr.]: effect on nutrient uptake, yield and internal tipburn. Large applications of mineral fertilizers in Chinese cabbage (Brassica pekinensis) increased growth, total nitrogen and nitrate concentrations at harvest, and increased the occurrence of internal tipburn. Green mulch, as the only fertilizer or in combination with small amounts of mineral fertilizers, resulted in slower growth and lower total nitrogen and nitrate concentrations at harvest, and also prevented the occurrence of internal tipburn. No visible symptoms of nutrient deficiencies were detected, but plant analyses showed that the concentrations of magnesium, zinc, manganese and copper were below the estimated sufficiency limits in all fertilizer regimes. High soil pH, 6.4-6.8, and large amounts of calcium in the soil decreased the availability of these elements. The results demonstrate the importance of simultaneous analyses of several elements in revealing suboptimal concentrations and/or imbalances that depress yield and quality but do not result in visible symptoms. The results also indicate that organic fertilizers such as green mulch may be more suitable than mineral fertilizers in preventing the occurrence of physiological disorders such as tipburn.

Jaiswal *et al.* (1997) conducted three pre-production verification trials, one each on off-season (summer) radish, carrot and Chinese cabbage were carried out at various Outreach Research (OR) and Off-Station Research (OSR) Sites in Lumle Agricultural Research Centre's Research Command Area in an altitudinal range of 430-2000 m asl. Carrot cultivars New Kuroda and Early Nantes performed well during the off-season (summer) with Early Nantes performing slightly better than New Kuroda. On average (over 10 locations) Early Nantes out yielded New Kuroda by 14% irrespective of mulching practice. Farmers and consumers from most of the sites preferred Early Nantes for its good yield, attractive root colour and shape, and comparatively higher root sugar content.

An experiment was conducted at the Horticultural Farm of Bangladesh Agricultural University, Mymensingh during the period from October, 2000 to February, 2001 by Shamim and Kamruzzaman (2004) to study the effect of four levels of nitrogen and mulching on growth and yield of Chinese cabbage and found that levels of nitrogen and mulching had significant influence on the growth and yield of Chinese cabbage. The maximum plant height, spread of plant, days to initiation of head, thickness of head, diameter of head, number of roots/plant, root length, stem length, number of folded and unfolded leaves/plant, fresh weight roots, dry matter of head, days to head maturity, compactness of head, fresh weight of head, marketable yield (77.13 t/ha) and gross yield (103.90 t/ha) were recorded when nitrogen was applied at the rate of 240 kg/ha. The highest gross yield (104.04 t/ha) was obtained from the black polythene mulch followed by water hyacinth mulch (99.60 t/ha). Black polythene mulch produced the highest marketable yield (78.14 t/ha). The maximum gross yield (118.4 t/ha) and marketable yield (94.03 t/ha) were found in the treatment combination of 240 kg N/ha with polythene mulch.



Chapter iii

MATEIALS AND METHODS

Chapter I11

MATERIALS AND METHODS

An experiment was conducted in the Horticulture Farm of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2005 to December 2005 to study the effect of different levels of nitrogen and mulching on growth and yield of Chinese cabbage. This chapter includes materials and methods that were used conducting in the experiment. It consists of a short description of locations of the experimental site, characteristics of soil, climate, materials used for the seedlings, treatment of the investigation, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data collection procedure, economic and statistical analysis etc. The details regarding materials and methods of this experiment are presented below under the following headings -

3.1 Experimental Site

The location of the site in $23^{0}74^{/}$ N latitude and $90^{0}35^{/}$ E longitude with an elevation of 8.2 meter from sea level (Anon, 1989).

3.2 Characteristics of Soil

The soil of the experimental area was non-calcarious dark grey and belongs to the Modhupur Tract (UNDP, 1988) under AEZ 28. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The 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 I.

3.3 Weather Condition 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 temperature were 29.45^{0}C and 13.86^{0}C, respectively. Details of the metrological data of air temperature, relative humidity, rainfalls and sunshine during the period of the experiment was collected from the Bangladesh Meteorological Department (Climate Division) and presented in Appendix II.

3.4 Planting Materials

In this research work, the seeds of Chinese cabbage were used which was produced by Takii and Co. Ltd. Japan. The seeds were collected from Dhaka Seed Store, Siddique Bazar, Dhaka.

3.5 Raising of seedling

The seedlings were raised at the Horticulture Farm, SAU, Dhaka under special care in two 3 × 1 m size seed beds. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease cupravit fungicide were applied. Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Ten (10) grams of seeds were sown in each seedbed on October 27, 2005. After sowing, the seeds were covered with finished light soil. At the end of germination shading was done by bamboo mat (chati) over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding and mulching were done as and when necessary to provide seedlings with ideal condition for better growth.

3.6 Treatment of the Experiment

The experiment was designed to study the effects of different level of N and mulch materials on growth and yield of Chinese cabbage. The experiment considered of two factors. Details are presented below:

Factor A: Levels of N fertilizer (4 levels)

i. N_0 (0 kg N/ha)/Control

ii. N_1 (160 kg N/ha)

iii. N_2 (200 kg N/ha)

iv. N_3 (250 kg N/ha)

Factor B: Mulches (4 levels)

i. M_0 (No mulching)/control

ii. M_1 (Black polythene mulch)

iii. M_2 (Saw dust mulch)

iv. M_3 (Water hyacinth mulch)

There were 16 (4 × 4) treatment combinations such as N_0M_0, N_0M_1, N_0M_2, N_0M_3, N_1M_0, N_1M_1, N_1M_2, N_1M_3, N_2M_0, N_2M_1, N_2M_2, N_2M_3, N_3M_0, N_3M_1, N_3M_2 and N_3M_3.

3.7 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 16 plots where 16 treatment combinations were allotted at random. There were 48 unit plots altogether in the experiment. The size of the plot was 3 × 1 m. The distance between two blocks and two plots were kept 1 m and 0 m, respectively. The layout of the experiment is shown in Figure 1.

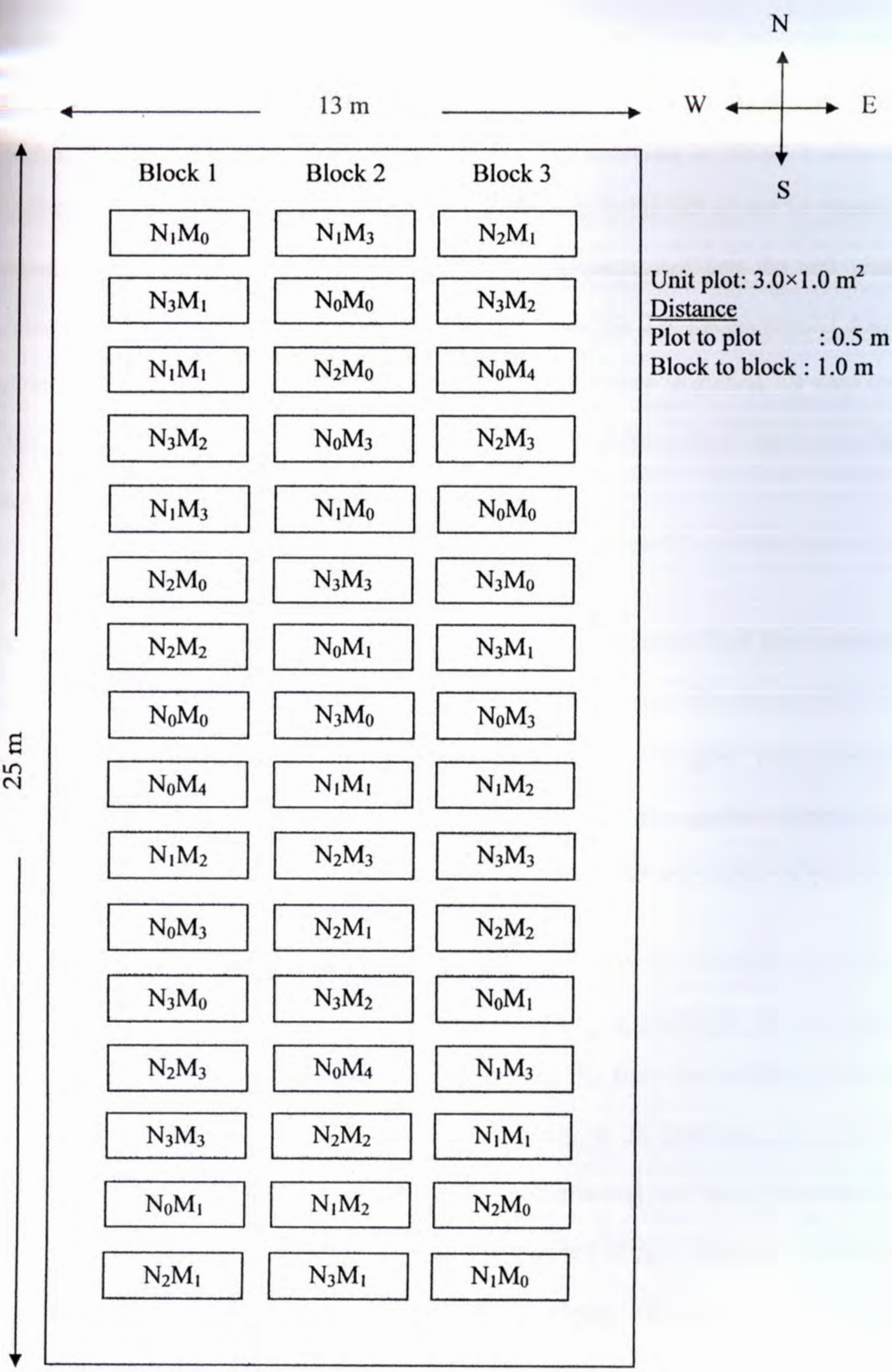


Figure 1. Layout of the experiment

3.8 Preparation of the Main Field

The selected experimental plot was opened in the last week of October 2005 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 mentioned in section 3.6. Recommended doses of well-rotten cowdung manure and chemical fertilizers as indicated in section 3.9 were mixed with the soil of each unit plot. The soil was treated with fungicide cupravit against the fungal attack.

3.9 Application of Manure and Fertilizers

Well decomposed cowdung manure 10 t/ha was applied in the time of final land preparation. The sources of fertilizers used for N, P, K, S, Zn and B were taken from the urea, TSP (150 kg/ha), MP (200 kg/ha), Gypsum (100 kg/ha) and zinc sulphate (30 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.

3.10 Transplanting of Seedlings in the Main Field

Healthy and uniform sized thirty days old seedlings were transplanted in the main field on November 26, 2005. The seedlings were uprooted carefully from the seedbed to avoid any damage to the root system. To minimize the roots damage of the seedlings the seedbed was watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. During transplanting a spacing of 30 × 50 cm between raw to raw and plant to plants were maintained. Thus each unit plot accommodated 20 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 receiving dew. A number of seedlings were also planted in the border of the experiment plots for gap filling if necessary later on.

3.11 Application of Mulch Treatment

Mulches of black polythene sheet saw dust and water hyacinth were provided immediately after seedling transplanting where small holes were made on the mulches with maintaining proper spacing for seedling transplanting. The thickness of water hyacinth and saw dust were maintained near about 10 cm.

3.12 Intercultural operation

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

3.13 Irrigation

Light over-head irrigation was provided with a wateringcan to the plots immediately after transplanting. The un-mulched plot had to be irrigated more frequently than the mulch plots. As a consequence, the amount of irrigation water was much higher in un-mulched plots which were calculated from the amount of water discharged from the hosepipe per minutes.

3.14 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 on border line. The transplanted seedlings were shading and watering for 07 days continued for the proper establishment of the seedlings.

3.15 Weeding

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

3.16 Plant Protection

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

3.17 Harvesting

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

3.18 Data recording

The data were collected from the inner rows of plants of each treatment to avoid the border effect. In each unit plot, 10 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 height, plant spread and number of loose leaves were counted at 20, 30, 40 days and at harvest. However, for gross and marketable yields per plot all the 10 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:

3.18.1 Plant height

The height of plant was recorded in centimeter (cm) at 20, 30, 40 days after transplanting (DAT) by using a meter scale. The height was measured from the ground level to the tip of the growing point of an individual plant. Mean value of the ten selected plants was calculated for each unit plot.

3.18.2 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 10 selected plants at 20, 30, 40 days after transplanting and at harvest and mean value was counted and was expressed in centimeter (cm).

3.18.3 Number of loose leaves per plant

Number of loose leaves of plant was counted at 20, 30, 40 days after transplanting and at harvest from ten plants and mean value was recorded.

3.18.4 Number of roots per plant

Main roots were washed out by water for removing soil from 10 sample selected plants after harvest. Then the numbers of lateral roots of plant were counted and the mean value per plant was calculated.

3.18.5 Length of roots

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

3.18.6 Fresh weight of roots

The fresh weight of roots was recorded after harvest and cleaning from the average of 10 plants and expressed in gram. The weight of the roots was recorded immediately after harvest.

3.18.7 Dry weight of roots

After recording the fresh weight of the roots, the roots were chopped and dried well in the sun. The sun-dried roots were then dried in an oven at 65^0C for 72 hours, until constant weight was achieved. The recorded weight, after oven drying, was the dry weight of root per plant.

3.18.8 Length of stem

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

3.18.9 Number of unfolded leaves per plant

The number of unfolded leaves was counted from outside to inner side and the mean values was counted.

3.18.10 Number of folded leaves per plant

The heads from sample plants were sectioned vertically at the middle position with a sharp knife. The number of folded leaves was counted from outside to inner side and the mean values was counted.

3.18.11 Fresh weight of unfolded leaves at harvest

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

9.18.12 Days to start of head formation

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

9.18.13 Days to head maturity

Days to head maturity was counted from the date of transplanting to the optimum condition for the harvest was recorded as treatment wise.

3.18.14 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.

3.18.15 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.

3.18.16 Head Volume

Head volume of Chinese cabbage was measured with the help of a meter scale. Firstly, diameter was measured than it converted into the volume.

$$\text{Volume} = \text{Length (cm)} \times \text{Breadth (cm)} \times \text{Height (cm)}$$

3.18.17 Fresh weight of head

The fresh weight of head at harvest was recorded as the average of 10 plants selected at random from each unit plot. The weight of the head was recorded immediately after harvest.

3.18.18 Dry weight of head

A sample of one hundred grams chopped head from 10 selected plants was dried freshly in the direct sun light for two days and then it was dried in an oven at 65^{0}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 in heads was calculated by using following formula.

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

3.18.19 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.

3.18.20 Gross yield per hectare

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

3.18.21 Marketable yield per plot

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

3.18.22 Marketable yield per hectare

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

3.18.23 Harvest Index

Harvest index for Chinese cabbage was calculated with the help of gross and marketable yield.

Harvest index = (Gross yield/Marketable yield) × 100

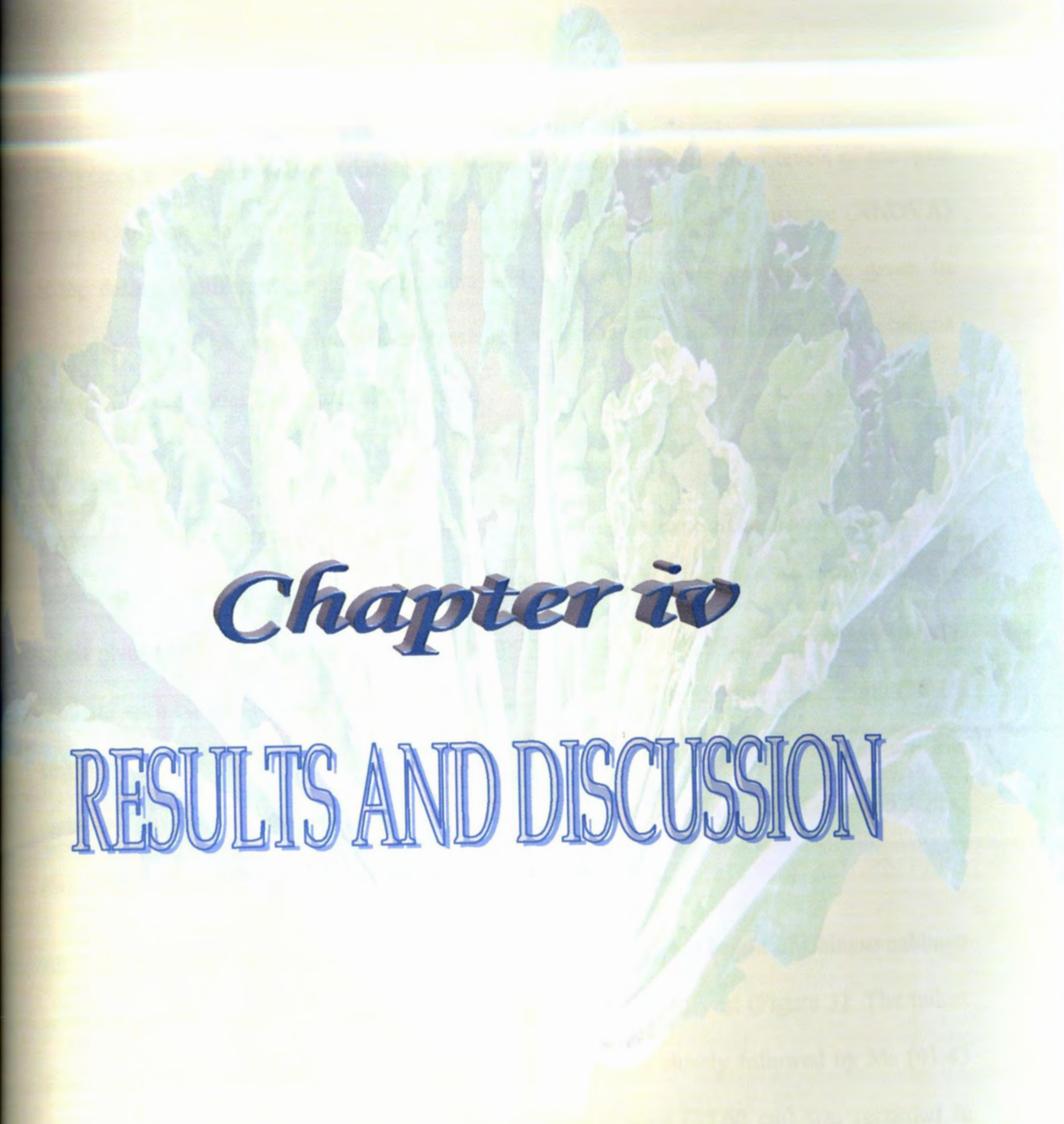
3.19 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference levels of N fertilizers and mulches on yield and yield contributing characters of Chinese cabbage. The mean values of all the characters were evaluated and analysis of variance was performing by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations means was estimated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984). All the result presented in Appendix III-V.

3.20 Economic analysis

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

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



Chapter iv

RESULTS AND DISCUSSION

Chapter IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of different levels of nitrogen and mulching on growth and yield of Chinese cabbage. The analysis of variance (ANOVA) of the data on different yield components and yield of Chinese cabbage are given in Appendix III-V. The results have been presented and discussed, and possible interpretations have been given under different parameters:

4.1 Plant height

Increasing level of nitrogen fertilizer applied in the present experiment showed a gradual increase in plant height of Chinese cabbage starting from 20 DAS till harvest (Figure 2). The tallest plant (43.12 cm) during harvesting period was recorded in N_3 which was statistically identical with N_1 and N_2, respectively (42.25 and 41.76 cm). The shortest plant height (36.15 cm) was recorded in the plot N_0. The results indicated that nitrogen fertilizer ensure the optimum condition for growth and development of plant. With the increase of nitrogen doses, plant height of Chinese cabbage increased up to certain level.

All mulches used in the present experiment showed increase plant height of Chinese cabbage comparing with control (no mulch) starting from 20 DAS to harvest (Figure 3). The tallest plant (44.50 cm) at harvest was recorded in M_1 which was closely followed by M_2 (41.43 cm). On the other hand, the shortest Chinese cabbage plant (37.60 cm) was recorded in without mulch. Probably, mulches increase the moisture content of soil which also ensures the advanced growth of plant. Alam *et al.* (1989) reported the similar trend of result.

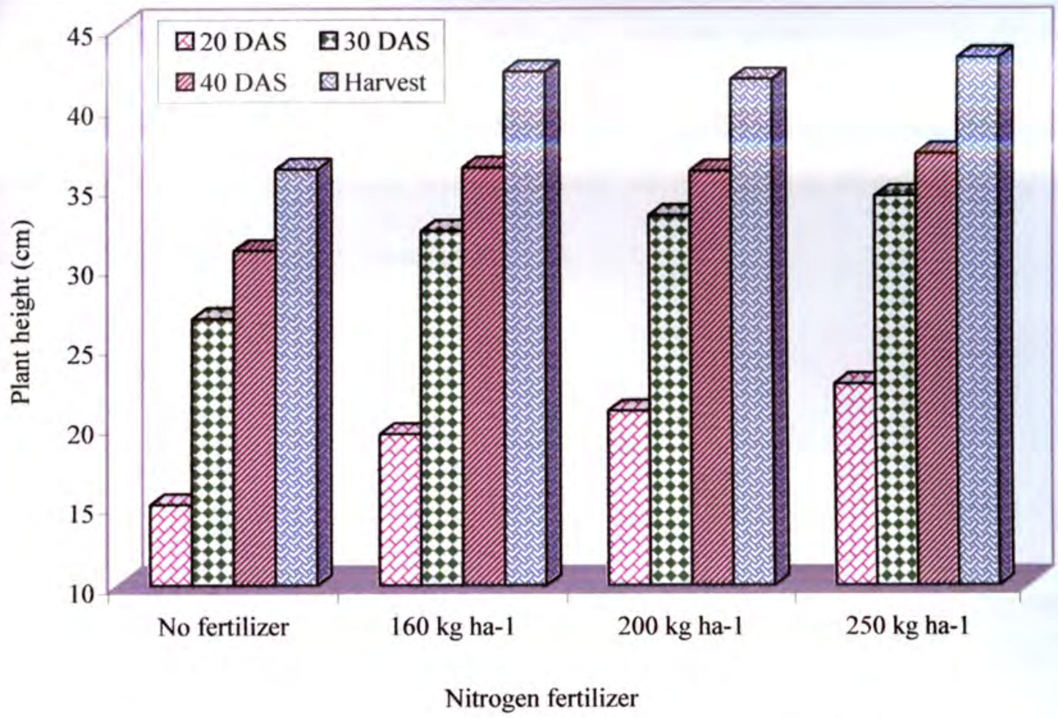


Figure 2. Effect of different levels of nitrogen on plant height in Chinese cabbage

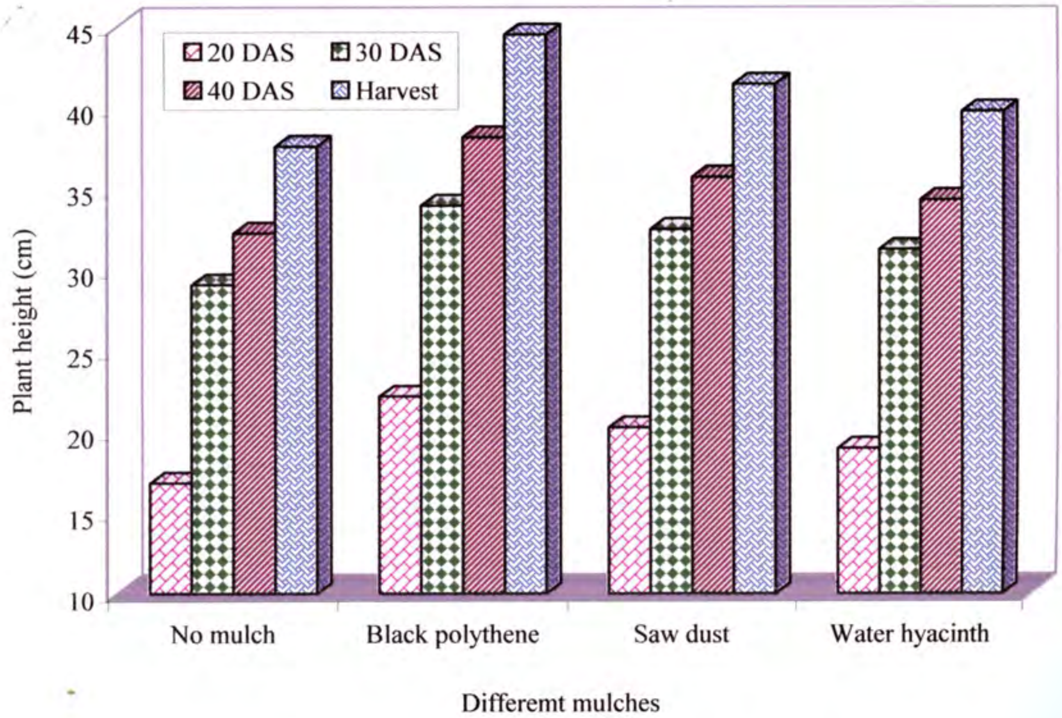


Figure 3. Effect of different mulches on plant height in Chinese cabbage

Interaction effect between nitrogen fertilizer and mulches demonstrated no significant differences expect 40 DAS in consideration of plant height of Chinese cabbage. But maximum height of Chinese cabbage during harvest (48.77 cm) was observed in N_3M_1 and the shortest plant (32.28 cm) was recorded in N_0M_0 (Table 1).

4.2 Spread of plant

All the level of nitrogen fertilizer, which was applied in the present showed a gradual increasing trend of plant spread of Chinese cabbage starting from 20 DAS to harvest (Figure 4). At harvest, the highest spread of Chinese cabbage plant (64.43 cm) was recorded in N_3 which was closely followed with N_2 (61.52 cm). The lowest spread of Chinese cabbage plant (48.38 cm) was recorded in N_0 which was closely followed by N_1 (57.23 cm). Nitrogen fertilizer increases the growth and development of plant and the ultimate results is the highest spread of plant.

Mulches used in the present research work showed increased spread of plant of Chinese cabbage comparing with control condition (no mulch) starting from 20 DAS to harvest (Figure 5). The highest spread of Chinese cabbage plant (58.28 cm) during harvesting was reported in M_1 which was closely followed by M_2 (56.01 cm). On the other hand the lowest spread of Chinese cabbage plant (49.58 cm) was recorded in M_0 which was closely followed by M_3 (53.14 cm). Good spread of plant indicates favorable growth and development which was the ultimate result of mulches.

Spread of plant showed no interaction effect between nitrogen fertilizer and mulches in Chinese cabbage. The maximum spread of Chinese cabbage plant at harvest (69.84 cm) was observed in N_3M_1 and the minimum (43.46 cm) was recorded in N_0M_0 (Table 1).

Table 1. Interaction effect between different level of nitrogen and mulching on plant height, spread of plant and number of leaves of Chinese cabbage

Nitrogen × Mulching		Plant height (cm) at				Spread of plant (cm) at				Number of loose leaves/plant at			
		20DAS	30DAS	40DAS	Harvest	20DAS	30DAS	40DAS	Harvest	20DAS	30DAS	40DAS	Harvest
N_0 (0 kg Nha^{-1})	M_0 (No mulch)	11.37	22.50	27.72 g	32.28	17.26	39.07	40.24	43.46	6.50 a	15.42	14.55	16.18
	M_1 (Black polythene)	17.45	29.50	32.26 ef	38.19	25.46	45.53	48.72	52.28	4.23 cd	12.67	11.25	12.15
	M_2 (Saw dust)	16.55	28.46	30.63 fg	35.55	24.32	44.26	47.33	50.84	4.52 c	14.77	13.67	15.09
	M_3 (Water hyacinth)	14.96	26.60	33.53 def	38.56	22.42	42.40	43.67	46.96	5.50 b	14.23	13.55	14.97
N_1(160 kg Nha^{-1})	M_0 (No mulch)	18.34	30.48	33.61 def	39.32	28.03	46.33	49.62	53.27	3.97 de	14.22	13.38	14.79
	M_1 (Black polythene)	21.75	33.35	38.80 ab	45.29	31.32	53.38	57.91	61.72	3.38 efg	11.60	11.00	12.21
	M_2 (Saw dust)	19.23	32.69	36.26bcd	42.16	30.37	51.36	54.93	58.90	3.53 efg	11.45	10.70	12.22
	M_3 (Water hyacinth)	18.70	32.57	36.33bcd	42.21	28.68	48.40	51.59	55.02	3.53 efg	13.90	13.22	14.61
N_2(200 kg Nha^{-1})	M_0 (No mulch)	18.60	31.59	33.18 def	38.82	27.29	47.30	53.27	56.46	3.90 def	14.13	13.37	14.77
	M_1 (Black polythene)	23.29	35.57	39.50 ab	45.76	34.68	56.34	61.23	65.84	3.17 g	11.43	11.07	12.29
	M_2 (Saw dust)	21.69	33.32	37.34 bc	42.94	32.26	53.53	59.34	62.90	3.55 efg	11.38	10.52	11.36
	M_3 (Water hyacinth)	20.24	32.43	34.07cdef	39.52	29.33	50.66	57.45	60.89	3.70defg	13.78	13.02	14.06
N_3(250 kg Nha^{-1})	M_0 (No mulch)	18.95	31.65	34.47 cde	39.97	28.33	49.56	55.21	58.92	3.78 def	13.45	12.80	14.16
	M_1 (Black polythene)	26.21	37.37	42.12 a	48.77	36.20	57.75	65.25	69.84	3.10 g	10.33	9.28	10.36
	M_2 (Saw dust)	23.50	35.45	38.59 b	45.04	34.24	57.41	62.45	66.53	3.33 fg	11.27	10.30	11.46
	M_3 (Water hyacinth)	21.96	33.33	33.27 def	38.70	31.52	54.76	59.86	62.45	3.53 efg	13.27	12.48	13.82
LSD (0.05)		--	--	3.189	--	--	--	--	--	0.522	--	--	--
Level of significance		NS	NS	*	NS	NS	NS	NS	NS	**	NS	NS	NS
CV (%)		8.24	6.64	5.45	4.54	6.28	5.07	4.26	4.62	7.91	10.66	8.14	9.86

NS : Not significant; ** : Significant at 0.01 level of probability

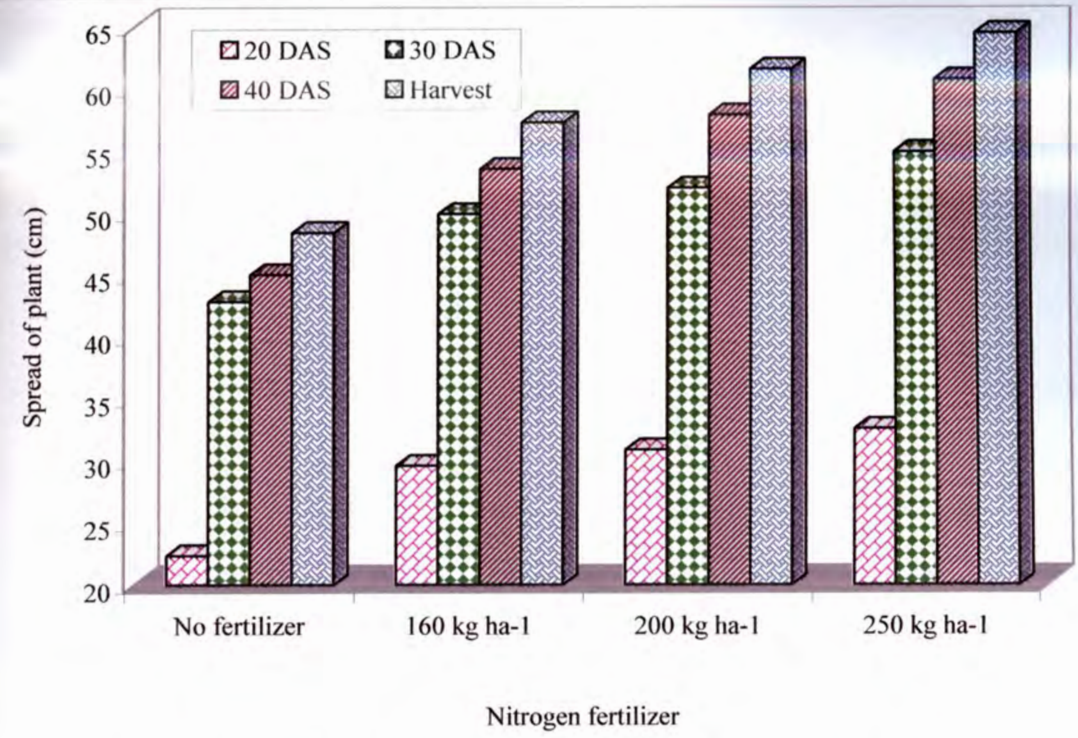


Figure 4. Effect of different levels of nitrogen on spread of plant in Chinese cabbage

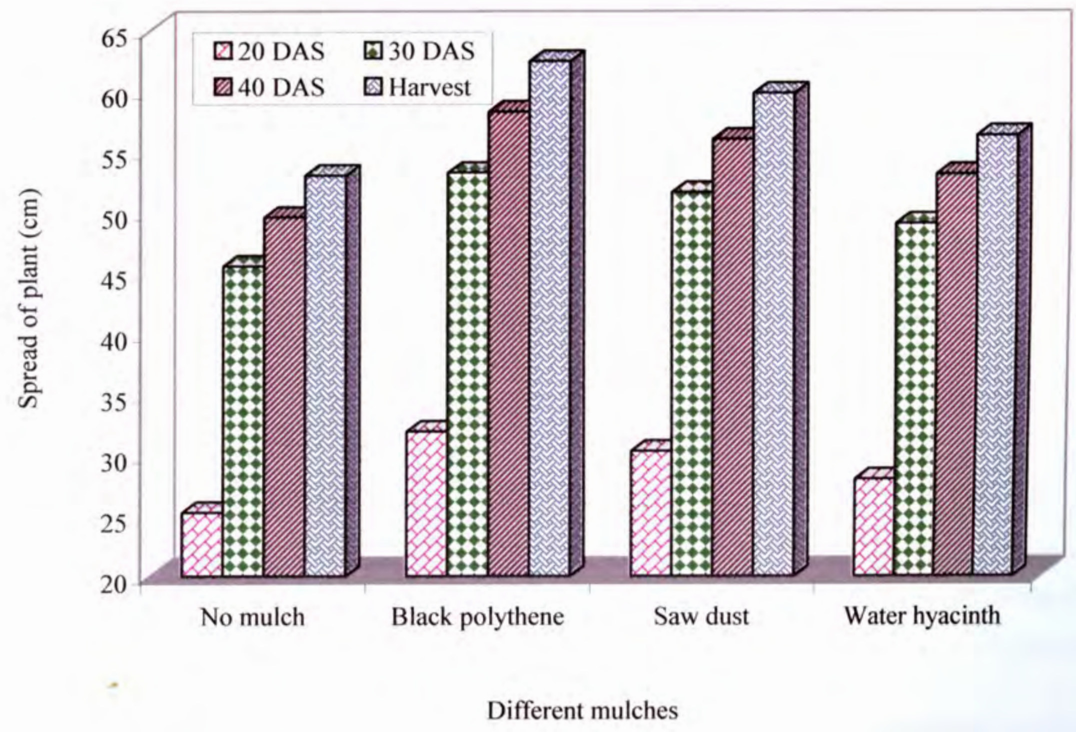


Figure 5. Effect of different levels of mulches on spread of plant in Chinese cabbage

4.3 Number of loose leaves per plant

Different levels of nitrogen fertilizer showed a steady decrease in number of loose leaves of Chinese cabbage starting from 20 DAS till harvest (Figure 6). The lowest number of loose Chinese cabbage leaves (12.45) was recorded in N_3 which was statistically similar to N_2 and N_1 (13.12 and 13.46), respectively and the highest number of loose leaves (14.60) at harvest was recorded in N_0. The results indicated that nitrogen fertilizer decreased the number of loose leaves as well as ensure the maximum compactness head of Chinese cabbage.

Mulches that were used in the present experiment showed decreased number of loose leaves of Chinese cabbage comparing with control (no mulch) starting from 20 DAS to harvest (Figure 7). The minimum number of loose leaves for Chinese cabbage plant (11.75) during harvest was recorded in M_1 which was statistically identical with M_2 (12.53). On the other hand, the highest number of loose leaves of Chinese cabbage plant (14.97) was recorded in M_0 which was statistically similar to M_3 (14.36).

Interaction effect between nitrogen fertilizer and mulches showed no significant differences expect 20 DAS in consideration of number of loose leaves per plant of Chinese cabbage. Minimum number of loose leaves (10.36) of Chinese cabbage at harvest was observed in N_3M_1 and the maximum number of loose leaves/plant (16.18) was recorded in N_0M_0 (Table 1).

4.4 Number of roots per plant

Number of roots per plant of Chinese cabbage showed statistically significant differences with different doses of nitrogen fertilizer applied in the present piece of experiment (Appendix IV). All the level of nitrogen fertilizer showed a gradual increasing tendency of number of roots per plant of Chinese cabbage (Table 2). The highest number of roots per

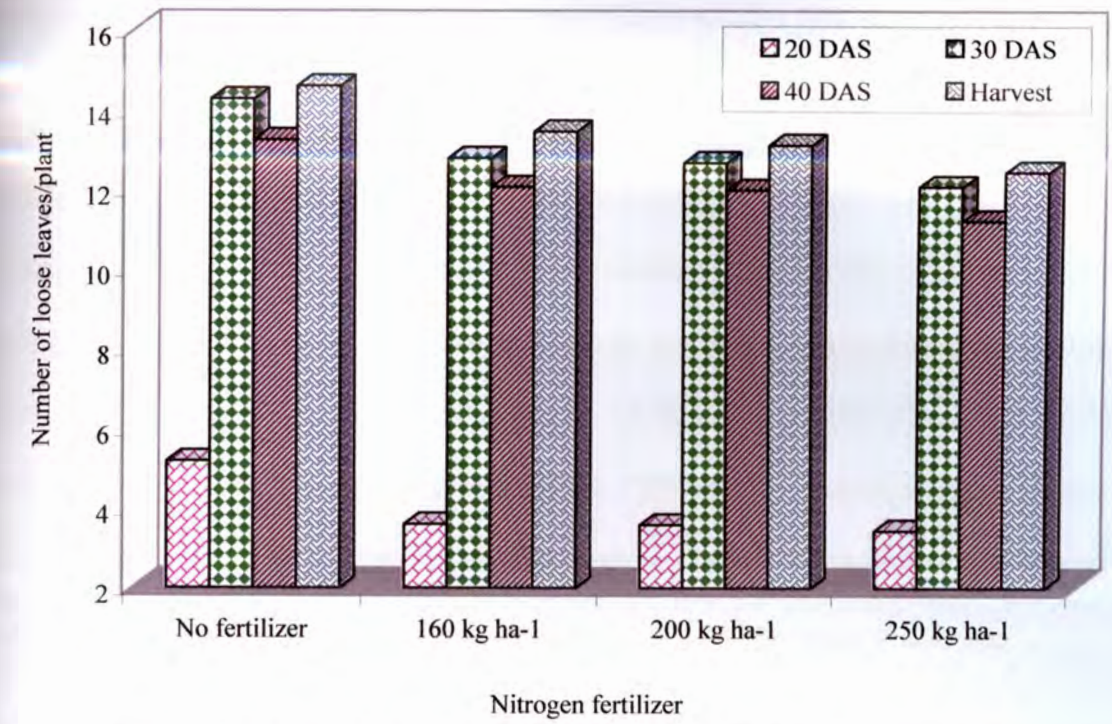


Figure 6. Effect of different levels of nitrogen fertilizer on number of loose leaves/plant in Chinese cabbage

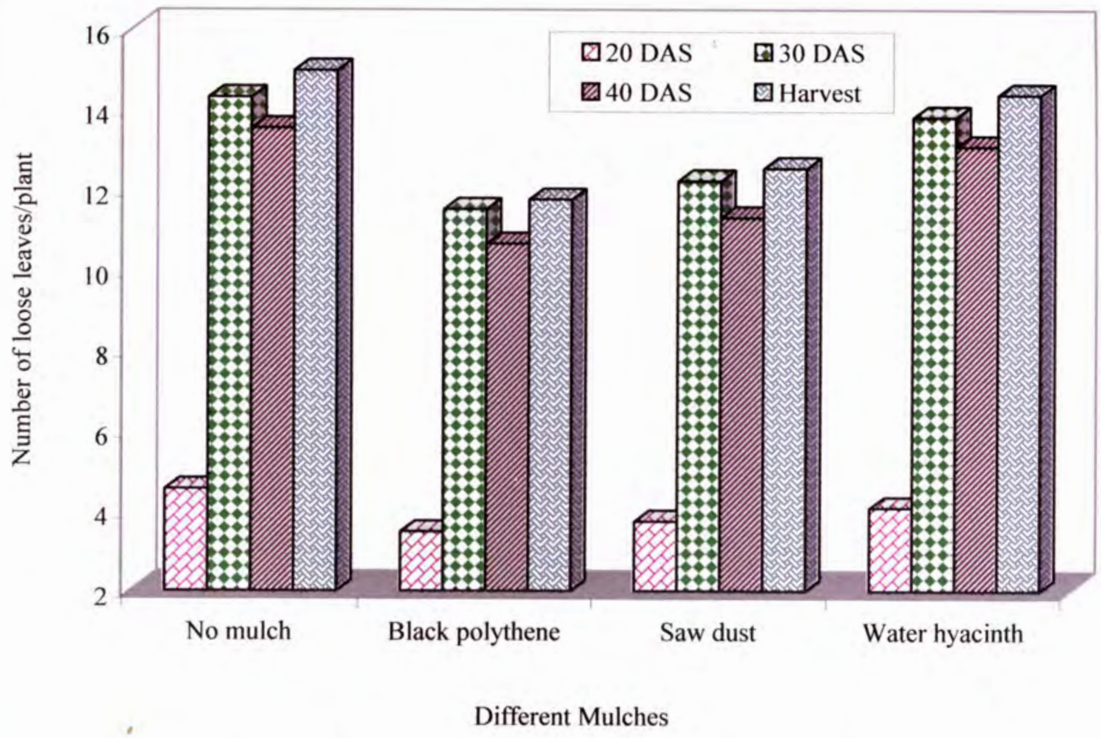


Figure 7. Effect of different mulches on number of loose leaves/plant in Chinese cabbage

plant (27.38) was recorded in N_3 which was statistically similar with the nitrogen doses at M_2 (25.51) while the minimum number of roots per plant of Chinese cabbage (21.88) was recorded in N_0.

Number of roots per plant at different mulches showed a statistically significant variation. The highest number of roots per plant of Chinese cabbage (26.41) during harvesting was recorded in M_1 which was closely followed by M_2 (25.56). On the other hand the lowest number of roots per plant of Chinese cabbage (23.37) was recorded in M_0 which was statistically similar with M_3 (23.64). Generally mulches ensure the optimum moisture content of soil and the ultimate results in the highest number of roots per plant (Table 3).

Number of roots per plant in Chinese cabbage showed no statistically difference in relation with interaction effect between nitrogen fertilizer and mulches. The maximum number of roots per plant (29.48) was recorded in N_3M_1 and the minimum (20.48) was recorded in N_0M_0 (Table 4). Batsei *et al*. (1979) disagree with the present findings.

4.5 Root length

Root length of Chinese cabbage showed statistically significant variation and longest roots per plant of Chinese cabbage (26.88 cm) was recorded in N_3 which was statistically similar to N_2 and N_1 (26.23 cm and 25.11 cm, respectively). The lowest length of roots per plant of Chinese cabbage (20.37 cm) was recorded from N_0 (Table 2).

The longest root per plant of Chinese cabbage (26.92 cm) was recorded in M_1 which was statistically parallel by M_2 (25.27 cm). On the other hand, the shortest root per plant of Chinese cabbage (22.16 cm) was recorded in M_0 which was closely followed to M_3 (24.24 cm). Generally, mulches ensure the optimum soil moisture for proper root development, and these conditions enhance root development as well as increase root length (Table 3). Chen *at al* (2004) reported the similar result earlier from their trial.

Table 2. Main effect of different level of nitrogen on yield contributing characters of Chinese cabbage

Nitrogen	No. of Roots/ plant	Length of roots (cm)	Fresh weight of roots/ plant	Dry weight of roots /plant	Length of stem (cm)	Fresh Wt. unfolded leaves/plant (g)	Days to initiation of head from seed sowing	Thickness of head (cm)	Diameter of head (cm)
N_0 (No N fertilizer)	21.88 c	20.37 b	12.37 c	2.19 b	4.92 b	378.52 d	46.80 a	18.98 c	14.21 b
N_1 (160 kg N ha^{-1})	24.23 bc	25.11 a	15.30 b	2.36 a	5.45 a	431.90 c	41.37 b	22.75 b	16.08 a
N_2 (200 kg N ha^{-1})	25.51 ab	26.23 a	16.20 b	2.43 a	5.64 a	456.05 b	42.36 b	24.23 a	16.55 a
N_3 (250 kg N ha^{-1})	27.38 a	26.88 a	17.39 a	2.49 a	5.55 a	482.71 a	40.96 b	25.18 a	17.06 a
LSD (0.05)	2.383	1.724	1.008	0.144	0.237	12.85	1.730	1.233	1.049
Level of significance	**	**	**	**	**	**	**	**	**

** : Significant at 0.01 level of probability

Table 3. Main effect of different mulching on yield contributing characters of Chinese cabbage

Mulching	No. of Roots/ plant	Length of roots (cm)	Fresh weight of roots/plant	Dry weight of roots /plant	Length of stem (cm)	Fresh Wt. unfolded leaves/plant (g)	Days to initiation of head from seed sowing	Thickness of head (cm)	Diameter of head (cm)
M_0 (No mulch)	23.37 b	22.16 c	13.40 c	2.22 c	5.02 c	391.45 c	45.37 a	20.81 c	15.10 c
M_1 (Black polythene)	26.41 a	26.92 a	17.08 a	2.52 a	5.41 b	469.45 a	41.17 c	24.74 a	16.86 a
M_2 (Saw dust)	25.56 ab	25.27 ab	16.14 a	2.36 bc	5.83 a	464.30 a	41.67 bc	23.27 b	16.40 ab
M_3 (Water hyacinth)	23.64 b	24.24 b	14.64 b	2.38 ab	5.29 b	423.98 b	43.27 b	22.31 b	15.54 bc
LSD (0.05)	2.383	1.724	1.008	0.144	0.237	12.85	1.730	1.233	1.049
Level of significance	*	**	**	**	**	**	**	**	**

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

Table 4. Interaction effect between different level of nitrogen and mulching on yield contributing characters of Chinese cabbage

Nitrogen × Mulching		Roots/ plant (No.)	Root length (cm)	Fresh weight of roots/ plant	Dry weight of roots /plant	Stem length (cm)	Folded leaves/ plant (No.)	Unfolded leaves/ plant (No.)	Wt. of unfolded leaves/ plant (g)	Days to initiation of head from seed sowing	Thickness of head (cm)	Diameter of head (cm)
N_0 (0 kgNha^{-1})	M_0 (No mulch)	22.97	15.72	10.55	2.12	3.83 e	32.81 i	16.60	324.73	48.51	13.95 h	12.55
	M_1 (Black polythene)	22.25	23.22	13.75	2.33	5.10 cd	48.54 gh	13.75	406.07	46.59	21.54 efg	15.70
	M_2 (Saw dust)	21.80	21.65	13.51	2.15	5.77 ab	46.86 gh	14.24	399.15	45.57	20.31 g	14.99
	M_3 (Water hyacinth)	20.48	20.90	11.66	2.16	4.96 d	43.61 h	16.41	384.14	46.54	20.11 g	13.61
N_1(160 kgNha^{-1})	M_0 (No mulch)	22.53	23.63	13.91	2.18	5.20 cd	49.76 defg	14.77	399.57	45.48	22.90bcdef	15.63
	M_1 (Black polythene)	26.33	26.93	16.67	2.51	5.40 bcd	54.25 abcd	12.63	455.75	38.81	24.60 abcd	16.74
	M_2 (Saw dust)	24.50	25.23	15.84	2.38	5.85 ab	52.50 bcde	13.12	456.24	40.49	22.30 cdefg	16.60
	M_3 (Water hyacinth)	23.53	24.65	14.77	2.37	5.33 bcd	51.31bcde	12.91	416.03	40.68	21.21fg	15.33
N_2(200kgNha^{-1})	M_0 (No mulch)	23.33	24.75	14.50	2.26	5.47 bcd	50.78cdef	14.71	415.93	44.67	22.04 defg	15.90
	M_1 (Black polythene)	27.58	28.12	17.66	2.56	5.49 bcd	56.44 ab	11.75	483.69	39.93	26.32 a	17.20
	M_2 (Saw dust)	26.75	26.40	16.84	2.43	6.21 a	54.60 abc	12.52	485.88	41.34	24.89 abc	16.76
	M_3 (Water hyacinth)	24.37	25.67	15.80	2.45	5.39 bcd	49.63 fgh	12.68	438.68	43.51	23.68abcde	16.35
N_3(250 kgNha^{-1})	M_0 (No mulch)	24.65	24.53	14.62	2.30	5.57 bc	53.93 bcde	13.57	425.56	42.84	24.36 abcd	16.33
	M_1 (Black polythene)	29.48	29.42	20.22	2.67	5.64 bc	58.66 a	10.13	532.28	39.35	26.51 a	17.79
	M_2 (Saw dust)	29.20	27.80	18.37	2.47	5.47 bcd	54.55 abc	11.45	515.94	39.29	25.59 ab	17.25
	M_3 (Water hyacinth)	26.17	25.75	16.33	2.53	5.49 bcd	54.88 abc	11.58	457.07	42.37	24.25 abcd	16.86
LSD (0.05)		-	--	--	--	0.475	4.018	--	--	--	2.467	--
Level of significance		NS	NS	NS	NS	**	**	NS	NS	NS	**	NS
CV (%)		11.55	8.39	7.90	7.30	5.27	4.74	7.56	3.52	4.84	6.49	7.88

NS : Not significant; ** : Significant at 0.01 level of probability

In consideration the interaction effect between nitrogen fertilizer and mulches length of roots per plant in Chinese cabbage showed no statistically distinction (Appendix IV). The highest length of roots per plant (29.42 cm) was recorded in N_3M_1 and the lowest (15.72 cm) was recorded in N_0M_0 (Table 4).

4.6 Fresh weight of roots per plant

A statistically significant distinction was recorded in respect of fresh weight of roots per plant in consideration with the application of nitrogen fertilizer. The maximum fresh weight of roots (17.39 g) was recorded in the plot with N_3 which was closely followed by N_2 and N_1 (16.20 g and 15.30 g, respectively) and the minimum fresh weight of roots per plant (12.37 g) was found from N_0 (Table 2).

Mulches that were used in the present experiment showed increases fresh weight of roots per plant of Chinese cabbage considering with control (no mulch). The maximum fresh weight of roots for Chinese cabbage plant (17.08 g) was recorded in M_1 which was statistically indistinguishable with M_2 (16.14 g). On the other hand the minimum fresh weight of roots per plant (13.40 g) was recorded in M_0 (Table 3).

Interaction effect between nitrogen fertilizer and mulches showed no significant differences in deliberation of fresh weight of roots per plant of Chinese cabbage. Maximum number of fresh weight of roots per plant (20.22 g) of Chinese cabbage was recorded in N_3M_1 and the minimum fresh weight of roots/plant (10.55 g) was recorded in N_0M_0 (Table 4).

4.7 Dry weight of roots per plant

Nitrogen fertilizer showed a gradual increasing tendency of dry weight of roots per plant (Table 2). The highest dry weight of roots per plant of Chinese cabbage (2.49 g) was recorded in N_3 which was statistically similar with N_2 and N_1 (2.43 and 2.36 g, respectively). The lowest dry weight of roots per plant of Chinese cabbage (2.19 g) was recorded in N_0.

4.9 Number of folded leaves per plant

All the levels of nitrogen fertilizer showed a steady increasing trend in the number of folded leaves (Figure 8). The greatest number of folded leaves of Chinese cabbage (55.51) was recorded in N_3. Application of N_2 and N_1 showed statistically similar results in this experiment. The lowest number of folded leaves for Chinese cabbage (42.96) was reported in N_0.

Mulches that were used in the present trial showed increase number of folded leaves of Chinese cabbage considering with control (Figure 9). The maximum number of folded leaves for Chinese cabbage plant (54.47) during harvest was recorded in M_1 which was statistically identical with M_2 (52.13). On the other hand the minimum number of folded leaves of Chinese cabbage plant (46.82) was recorded in M_0 which was statistically similar with M_3 (49.86). Hill (1982) recorded the highest folded leaves from black polythene mulch earlier from one of the experiment.

Interaction effect between nitrogen fertilizer and mulches showed a statistically significant difference in consideration of number of folded leaves/plant of Chinese cabbage. Maximum number of folded leaves (58.66) of Chinese cabbage at harvest was observed in N_3M_1 and the minimum number of folded leaves/plant (32.81) was recorded in N_0M_0 (Table 4).

4.10 Number of unfolded leaves per plant

Nitrogen fertilizer showed a gradual decreasing propensity of number of unfolded leaves per plant of Chinese cabbage (Figure 8). The highest number of unfolded leaves per plant of Chinese cabbage (15.23) was recorded in N_0 while the lowest number (11.68) was recorded from N_3 which was closely followed by M_2 (12.91).

Number of unfolded leaves/plant at different mulches showed a statistically significant variation. The highest of unfolded leaves per plant of Chinese cabbage (14.91) was

4.9 Number of folded leaves per plant

All the levels of nitrogen fertilizer showed a steady increasing trend in the number of folded leaves (Figure 8). The highest number of folded leaves of Chinese cabbage (55.51) was recorded in N_3. Application of N_2 and N_1 showed statistically similar results in this experiment. The lowest number of folded leaves for Chinese cabbage (42.96) was reported in N_0.

Mulches that were used in the present trial showed increase number of folded leaves of Chinese cabbage considering with control (Figure 9). The maximum number of folded leaves for Chinese cabbage plant (54.47) during harvest was recorded in M_1 which was statistically identical with M_2 (52.13). On the other hand the minimum number of folded leaves of Chinese cabbage plant (46.82) was recorded in M_0 which was statistically similar with M_3 (49.86). Hill (1982) recorded the highest folded leaves from black polythene mulch earlier from one of the experiment.

Interaction effect between nitrogen fertilizer and mulches showed a statistically significant difference in consideration of number of folded leaves/plant of Chinese cabbage. Maximum number of folded leaves (58.66) of Chinese cabbage at harvest was observed in N_3M_1 and the minimum number of folded leaves/plant (32.81) was recorded in N_0M_0 (Table 4).

4.10 Number of unfolded leaves per plant

Nitrogen fertilizer showed a gradual decreasing propensity of number of unfolded leaves per plant of Chinese cabbage (Figure 8). The highest number of unfolded leaves per plant of Chinese cabbage (15.23) was recorded in N_0 while the lowest number (11.68) was recorded from N_3 which was closely followed by M_2 (12.91).

Number of unfolded leaves/plant at different mulches showed a statistically significant variation. The highest number of unfolded leaves per plant of Chinese cabbage (14.91) was recorded in M_0 which was closely followed by M_3 water hyacinth (13.39). On the other hand the lowest number (12.07) was recorded in M_1 which was statistically similar with M_2 (12.83).

Number of unfolded leaves per plant in Chinese cabbage showed no statistically significant difference in relation with interaction effect between nitrogen fertilizer and mulches. The maximum number of unfolded leaves per plant (16.60) was recorded in N_0M_0 and the minimum (10.13) was recorded in N_3M_1 (Table 4).

4.11 Fresh weight of unfolded leaves at harvest

Fresh weight of unfolded leaves per plant showed statistically significant variation with different doses of nitrogen fertilizer applied in the present experiment. Nitrogen fertilizer showed a gradually increasing trend of fresh weight of unfolded leaves per plant of Chinese cabbage (Table 2). The highest weight of unfolded leaves per plant of (482.71 g) was recorded in N_3. On the other hand the lowest weight (378.52 g) was observed in N_0 which was closely followed by N_1 (431.90 g).

Weight of unfolded leaves per plant at different mulches showed statistically significant differences. The highest weight of unfolded leaves per plant of Chinese cabbage (469.45 g) was recorded in M_1 which was statistically similar with M_2 (464.30 g). On the other hand the lowest fresh weight (391.45 g) was recorded in M_0.

Interaction effect between nitrogen fertilizers and mulches showed no statistically significant difference in consideration with fresh weight of unfolded leaves per plant in Chinese cabbage. The highest weight of unfolded leaves per plant (532.28 g) was recorded in N_3M_1 (Table 4) and the lowest fresh weight of unfolded leaves per plant (324.73 g) was recorded in N_0M_0.

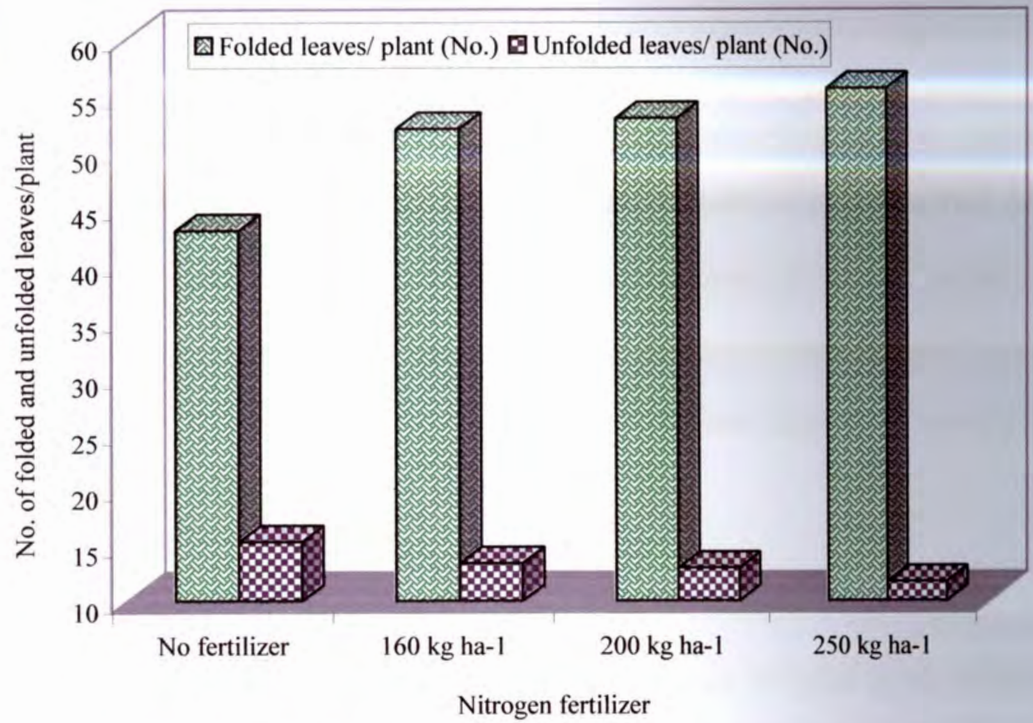


Figure 8. Effect of different level of nitrogen fertilizer on number of folded and unfolded leaves/plant in Chinese cabbage

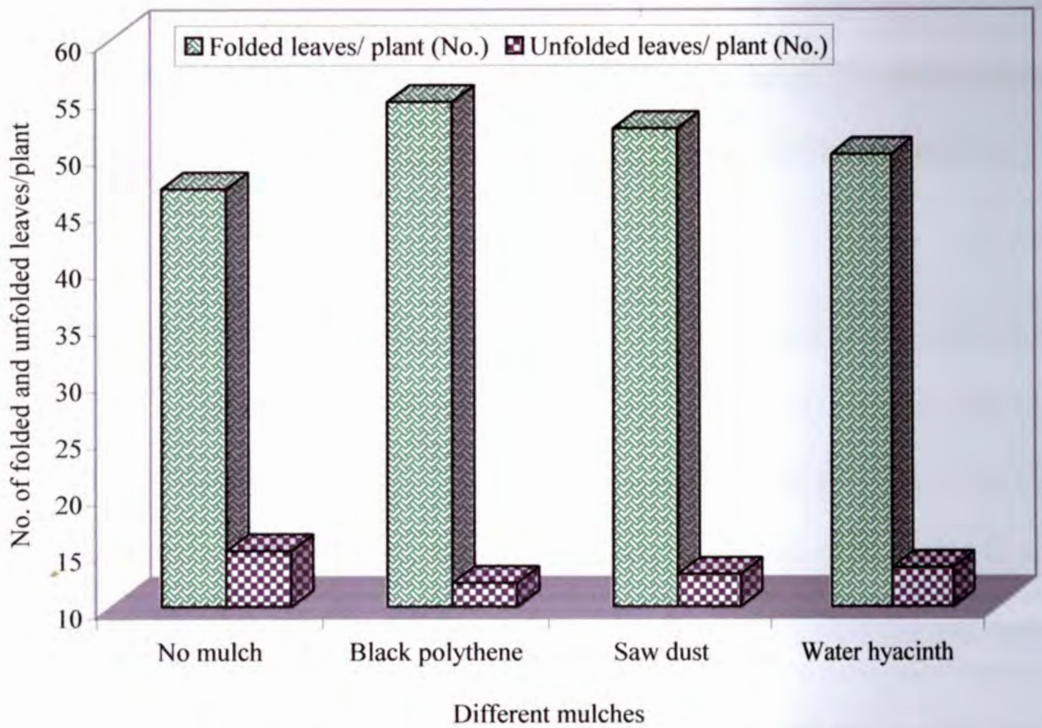


Figure 9. Effect of different mulches on number of folded and unfolded leaves/plant in Chinese cabbage

4.12 Days to start of head formation from seed sowing

Days to start of head formation from seed sowing of Chinese cabbage showed significant differences with different levels of nitrogen fertilizer application in the present trial. All the level of nitrogen fertilizer showed a gradual decreasing tendency of days to starting head formation of Chinese cabbage (Table 2). The longest duration to starting head formation (46.80) was recorded in N_0. On the other hand, the shortest duration to starting head formation (40.96) was recorded in the plot with N_3.

Days to start of head formation at different mulches showed differences. The longest duration to starting of head formation of Chinese cabbage (45.37) was recorded in M_0 which was closely followed by M_3 (43.27). On the other hand the shortest duration (41.17) was recorded in M_1.

Days to start of head formation in Chinese cabbage showed no statistically difference in relation with interaction effect between nitrogen fertilizer and mulches. The shortest duration (39.29) was recorded in N_3M_2 and the longest (48.51) was recorded in N_0M_0 (Table 4).

4.13 Thickness of head

Thickness of head of Chinese cabbage illustrated statistically significant distinction in relation with different doses of nitrogen applied in the present trial. The thickest head (25.18 cm) of Chinese cabbage was recorded from N_3 which was statistically similar to N_2 (24.23 cm). The thinnest head of Chinese cabbage (18.98 cm) was recorded in N_0 (Table 2) which was closely followed by N_1 (22.75 cm).

Different mulches showed a statistically significant disparity in consideration with thickness of head of Chinese cabbage. The thickest head of Chinese cabbage (24.74 cm) was recorded in M_1 which was closely followed by M_2 and M_3 (23.27 cm and 22.31 cm, respectively) and the thinnest head of Chinese cabbage (18.98 cm) was recorded in the plot with M_0 (Table 3).

In consideration the interaction effect between nitrogen fertilizer and mulches the thickness of head of Chinese cabbage showed a statistically significant variation. The thickest head of Chinese cabbage (26.51 cm) was recorded in N_3M_1 and the thinnest head (13.95 cm) was recorded in N_0M_0 (Table 4).

4.14 Diameter of head

Significant difference was recorded in diameter of head of Chinese cabbage with different doses of nitrogen fertilizer applied in the present experiment. The highest diameter head (17.06 cm) was recorded in N_3 which was statistically similar with N_2 and N_1 (16.55 cm and 16.08 cm, respectively). The lowest diameter of head (14.21 cm) was recorded in N_0 (Table 2).

Diameter of head at different mulches which was used in the present experiment showed significant variation. The highest diameter of head (16.86 cm) was recorded in M_1 which was statistically identical with N_2 (16.40 cm) and the lowest diameter (15.10 cm) was recorded in M_0.

Diameter of head in Chinese cabbage showed no statistically difference in relation with interaction effect between nitrogen fertilizer and mulches. The highest diameter of head (17.79 cm) was recorded in N_3M_1 and the lowest diameter of head (12.55 cm) was recorded in N_0M_0 (Table 4).

4.15 Head Volume

Statistically significant difference was recorded in head volume of Chinese cabbage with different doses of nitrogen fertilizer applied in the present trial. The highest volume of head

(3466.00 cm^3) was recorded in N_3 which was closely followed by N_2 and N_1 (3306.44 cm^3 and 3226.86 cm^3, respectively). On the other hand the lowest volume of head (2432.08 cm^3) was recorded from N_0 (Table 5).

Volume of head at different mulches which was used in the present experiment showed significant variation. The highest volume of head (3464.09 cm^3) was recorded in M_1 which was statistically similar with M_2 (3357.64 cm^3) and the lowest volume of head (2583.45 cm^3) was recorded in M_0.

In Chinese cabbage volume of head showed no statistically difference in relation with interaction effect between nitrogen fertilizer and mulches. The highest volume of head (3882.47 cm^3) was recorded in N_3M_1 and the lowest volume of head (1992.13 cm^3) was recorded in N_0M_0 (Table 7).

4.16 Days to head maturity

A statistically significant difference was recorded in days to of head maturity of Chinese cabbage with different doses of nitrogen fertilizer applied in the present piece of experiment (Appendix IV). The highest days to head maturity (27.45) was recorded in N_0 which was closely followed by N_1 (25.90) and the lowest days to head maturity (25.32) was recorded from N_3.

Days to head maturity at different mulches which was used in this experiment showed no statistically significant variation. But the highest days to head maturity (27.05) was recorded in M_0 and the lowest days (25.71) were recorded in M_1.

Days to head maturity in Chinese cabbage showed no statistically difference in relation with interaction effect between nitrogen fertilizer and mulches. The lowest days (24.48) was recorded in N_3M_2 and the highest days (28.64) was recorded in N_0M_0 (Table 7).

Table 5. Effect of different level of nitrogen on yield contributing characters and yield of Chinese cabbage

Nitrogen	Head volume	Days to head maturity from initiation	Fresh weight of head (Kg)	Dry weight of head (g)	Gross yield (Kg/plot)	Marketable yield (kg/plot)	Gross yield (t/ha)	Harvest Index
N_0 (No N fertilizer)	2432.08 c	27.45 a	1.57 c	10.42 c	31.40 c	20.37 c	104.65 c	64.53 b
N_1 (160 kg N ha^{-1})	3226.86 b	26.56 ab	2.18 ab	14.39 b	43.68 b	32.13 b	145.61 b	73.23 a
N_2 (200 kg N ha^{-1})	3306.44 b	25.90 b	2.26 b	14.64 ab	45.40 ab	33.19 b	151.32 ab	73.04 a
N_3 (250 kg N ha^{-1})	3466.00 a	25.32 b	2.43 b	15.30 a	46.81 a	36.02 a	156.02 a	76.59 a
LSD (0.05)	151.5	1.272	0.156	0.861	2.122	2.096	7.074	5.064
Level of significance	**	*	**	**	**	**	**	**

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

Table 6. Effect of different mulching on yield contributing characters and yield of Chinese cabbage

Mulching	Head volume	Days to head maturity from initiation	Fresh weight of head (Kg)	Dry weight of head (g)	Gross yield (Kg/plot)	Marketable yield (kg/plot)	Gross yield (t/ha)	Harvest Index
M_0 (No mulch)	2583.45 c	27.05	1.72 d	12.24 c	33.75 d	22.95 d	112.49 d	67.08 c
M_1 (Black polythene)	3464.09 a	25.71	2.44 a	15.64 a	47.52 a	36.98 a	158.39 a	77.60 a
M_2 (Saw dust)	3357.64 a	25.87	2.28 b	14.43 b	44.83 b	33.30 b	149.45 b	73.86 ab
M_3 (Water hyacinth)	3026.19 b	26.60	2.01 c	12.45 c	41.18 c	28.47 c	137.27 c	68.85 bc
LSD (0.05)	151.5	--	0.156	0.861	2.122	2.096	7.074	5.064
Level of significance	**	NS	**	**	**	**	**	**

NS : Not significant; ** : Significant at 0.01 level of probability

Table 7. Interaction effect between different level of nitrogen and mulching on yield contributing characters and yield of Chinese cabbage

Nitrogen × Mulching		Head volume	Days to head maturity from initiation	Fresh weight of head (Kg)	Dry weight of head (g)	Gross yield (Kg/plot)	Marketable yield (kg/plot)	Gross yield (t/ha)	Harvest Index
N_0 (0 $kgNha^{-1}$)	M_0 (No mulch)	1992.13	28.64	1.26	8.45	23.59	13.68	78.62	57.77
	M_1 (Black polythene)	2590.44	26.99	1.70	12.08	33.56	24.36	111.86	73.21
	M_2 (Saw dust)	2613.84	26.77	1.68	11.32	34.98	22.87	116.59	65.75
	M_3 (Water hyacinth)	2531.89	27.38	1.64	9.85	33.46	20.57	111.54	61.39
N_1(160 $kgNha^{-1}$)	M_0 (No mulch)	2692.86	27.48	1.80	12.41	35.58	24.49	118.61	68.97
	M_1 (Black polythene)	3696.47	25.71	2.53	16.51	49.79	39.54	165.97	79.45
	M_2 (Saw dust)	3565.47	26.40	2.40	15.12	47.76	34.83	159.19	73.09
	M_3 (Water hyacinth)	2952.63	26.65	1.98	13.53	41.60	29.65	138.66	71.42
N_2(200$kgNha^{-1}$)	M_0 (No mulch)	2752.21	26.52	1.84	13.53	36.28	25.94	120.92	71.54
	M_1 (Black polythene)	3686.99	24.68	2.64	16.87	52.48	40.62	174.93	77.68
	M_2 (Saw dust)	3546.78	25.81	2.48	15.59	49.38	35.67	164.61	72.21
	M_3 (Water hyacinth)	3239.77	26.60	2.10	12.57	43.45	30.55	144.82	70.72
N_3(250 $kgNha^{-1}$)	M_0 (No mulch)	2896.57	25.56	1.96	14.57	39.54	27.71	131.80	70.06
	M_1 (Black polythene)	3882.47	25.47	2.88	17.11	54.24	43.40	180.80	80.06
	M_2 (Saw dust)	3704.48	24.48	2.56	15.68	47.22	39.83	157.40	84.38
	M_3 (Water hyacinth)	3380.49	25.78	2.31	13.86	46.22	33.13	154.07	71.87
LSD (0.05)		--	--	--	--	--	--	--	--
Level of significance		NS	NS	NS	NS	NS	NS	NS	NS
CV (%)		5.85	5.80	8.82	7.54	6.09	6.32	6.09	8.45

NS : Not significant

4.17 Fresh weight of head

Nitrogen fertilizer showed a gradually increasing trend of fresh weight of head of Chinese cabbage (Table 5). The highest fresh weight of head per plant (2.43 kg) was recorded in N_3 which was closely followed by N_2 and N_1 (2.26 and 2.18 kg, respectively). On the other hand the lowest fresh weight of head (1.57 kg) was recorded from N_0.

Fresh weight of head per plant at different mulches showed significant differences. The highest fresh weight of head per plant of Chinese cabbage (2.44 kg) was recorded in M_1 (Table 6) which was closely followed by M_2 (2.28 kg). On the other hand the lowest fresh weight of head (1.72 kg) was recorded in M_0 which was closely followed by M_3 (2.01 kg).

Interaction effect between nitrogen fertilizers and mulches showed no statistically significant difference in consideration with fresh weight of head per plant in Chinese cabbage. The highest fresh weight of head per plant (2.88 kg) was recorded in N_3M_1 (Table 7) and the lowest fresh weight of head per plant (1.26 kg) was recorded in N_0M_0.

4.18 Dry weight of head

Nitrogen fertilizer showed statistically significant differences in consideration of dry weight of head per plant. A gradually increasing trend was found in dry weight of head of Chinese cabbage (Table 5). The highest dry weight of head per plant (15.30 g) was recorded in N_3 which was closely followed by N_2 and N_1 (14.67 g and 14.39 g, respectively). On the other hand the lowest dry weight of head (10.42 g) was recorded in N_0.

Dry weight of head per plant at different mulches showed statistically significant variation in the present trial. The highest dry weight of head per plant of Chinese cabbage (15.64 g) was recorded in M_1 (Table 6) which was closely followed by M_2 (14.43 g). On the other hand the lowest dry weight of head (12.24 g) was recorded in M_0 which was statistically similar with M_3 (12.45 g).

Interaction effect between nitrogen fertilizers and mulches showed no statistically significant difference in consideration of dry weight of head. The highest dry weight of head per plant (17.11 g) was recorded in N_3M_1 (Table 7) and the lowest dry weight of head per plant (8.45 g) was recorded in N_0M_0.

4.19 Gross yield per plot

In Chinese cabbage gross yield showed statistically significant differences with different doses of nitrogen fertilizer. All the level of nitrogen fertilizer showed a gradual increasing tendency to gross yield per plot (Table 5). The highest gross yield per plot of Chinese cabbage (46.81 kg) was recorded in N_3 which was statistically similar with N_2 (45.40 kg). On the other hand the lowest gross yield per plot of Chinese cabbage (31.40 kg) was recorded in N_0 which was closely followed by N_1 (43.68 kg).

The highest gross yield/plot of Chinese cabbage (47.52 kg) was recorded in M_1 which was closely followed by M_2 (44.83 kg). On the other hand the lowest gross yield of Chinese cabbage (33.75 kg) was recorded in M_0 which was closely followed by M_3 (41.18 kg). Generally mulches ensure the optimum moisture content and availability of soil nutrient of soil and the ultimate results in the highest growth and development as well as the highest gross yield (Table 6).

In Chinese cabbage gross yield per plot showed no statistically difference in relation with interaction effect between nitrogen fertilizer and mulches. The maximum gross yield per plot (54.54 kg) was recorded in N_3M_1 and the minimum gross yield per plot (23.59 kg) was recorded in N_0M_0 (Table 7).

4.20 Gross yield per hectare

Gross yield per hectare in Chinese cabbage showed statistically significant differentiation with different doses of nitrogen fertilizer applied in the present trial. All the level of nitrogen fertilizer showed a gradual increasing tendency to gross yield per hectare (Figure 10). The highest gross yield per hectare (156.02 ton) was recorded in N_3 which was statistically identical with N_2 (151.32 ton). On the other hand the lowest gross yield per hectare of Chinese cabbage (104.65 ton) was recorded in N_0.

Gross yield per hectare at different mulches applied in the present experiment showed a statistically significant variation (Appendix V). The highest yield of Chinese cabbage per hectare (158.39 ton) was recorded in M_1 (Figure 11) which was closely followed by M_2 (149.45 ton). On the other hand the lowest gross yield of Chinese cabbage (112.49 ton) was recorded in M_0 which was closely followed by M_3 (137.27 ton).

In Chinese cabbage gross yield per hectare showed no statistically variation in relation with interaction effect between nitrogen fertilizer and mulches. The maximum gross yield per hectare (180.80 ton) was recorded in N_3M_1 and the minimum gross yield per hectare (78.62 ton) was recorded in N_0M_0 (Figure 12).

4.21 Marketable yield per plot

Marketable yield showed statistically significant differences with different doses of nitrogen fertilizer. All the level of nitrogen fertilizer showed a gradual increasing tendency to marketable yield per plot (Table 5). The highest marketable yield per plot (36.02 kg) was recorded in N_3 which was closely followed with N_2 and N_1 (33.19 and 32.13 kg). On the contrary the lowest marketable yield per plot of Chinese cabbage (20.37 kg) was recorded in N_0.

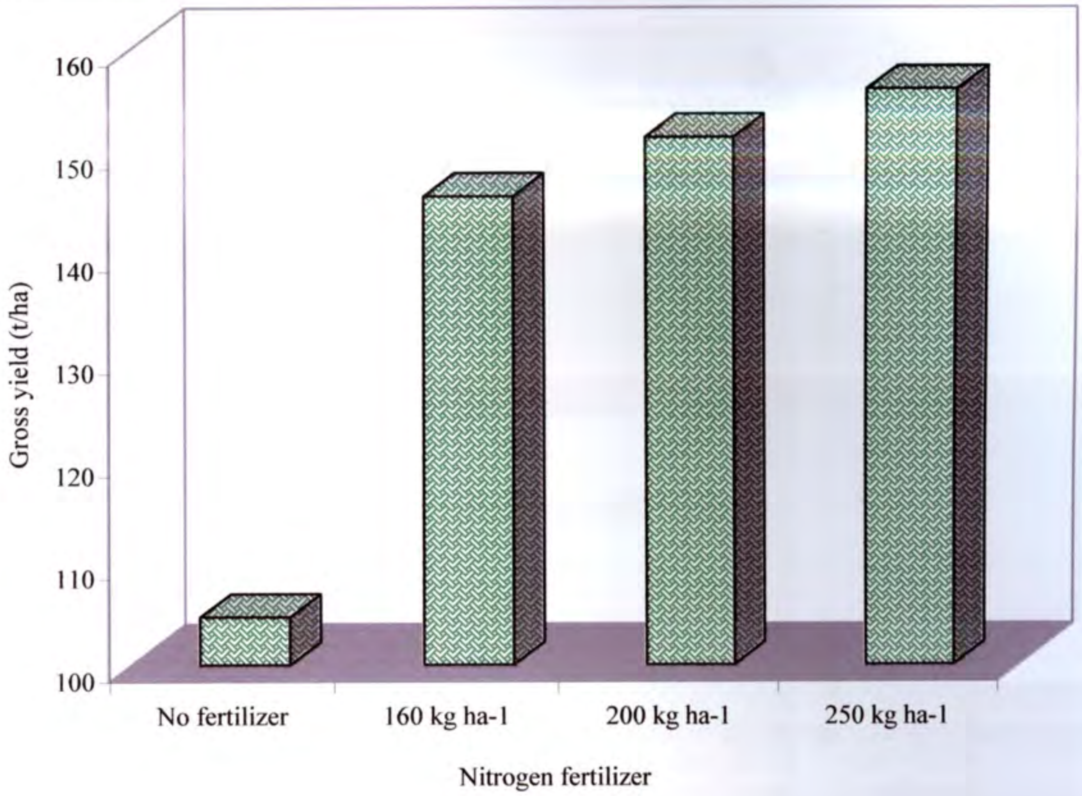


Figure 10. Effect of different level of nitrogen fertilizer on gross yield in Chinese cabbage

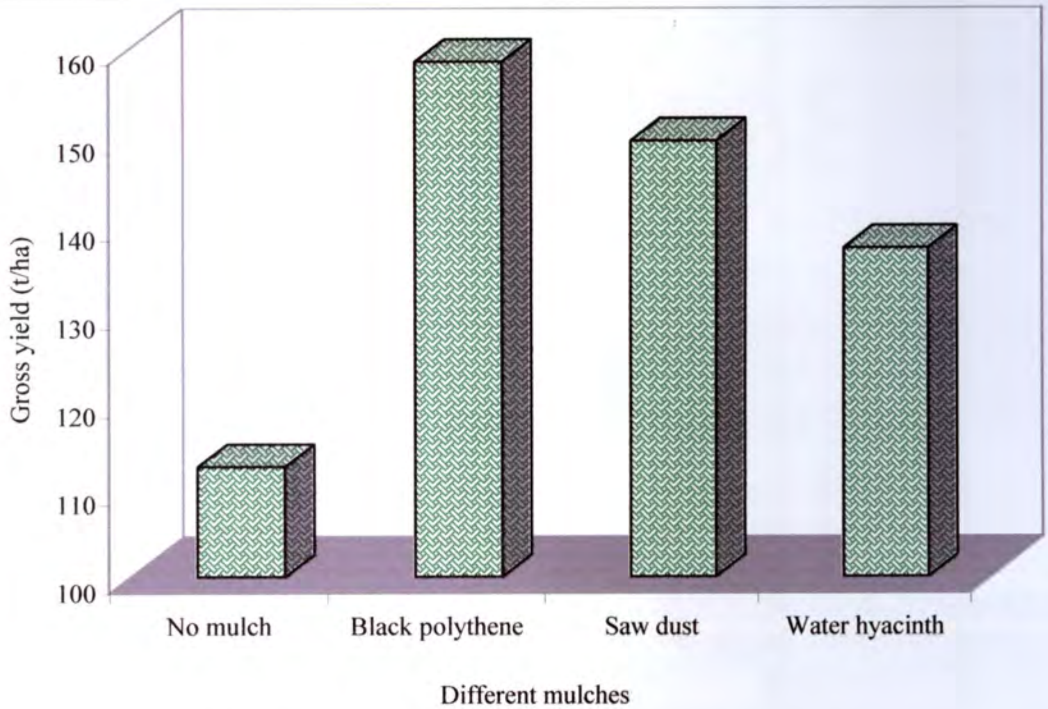


Figure 11. Effect of different mulches on gross yield in Chinese cabbage

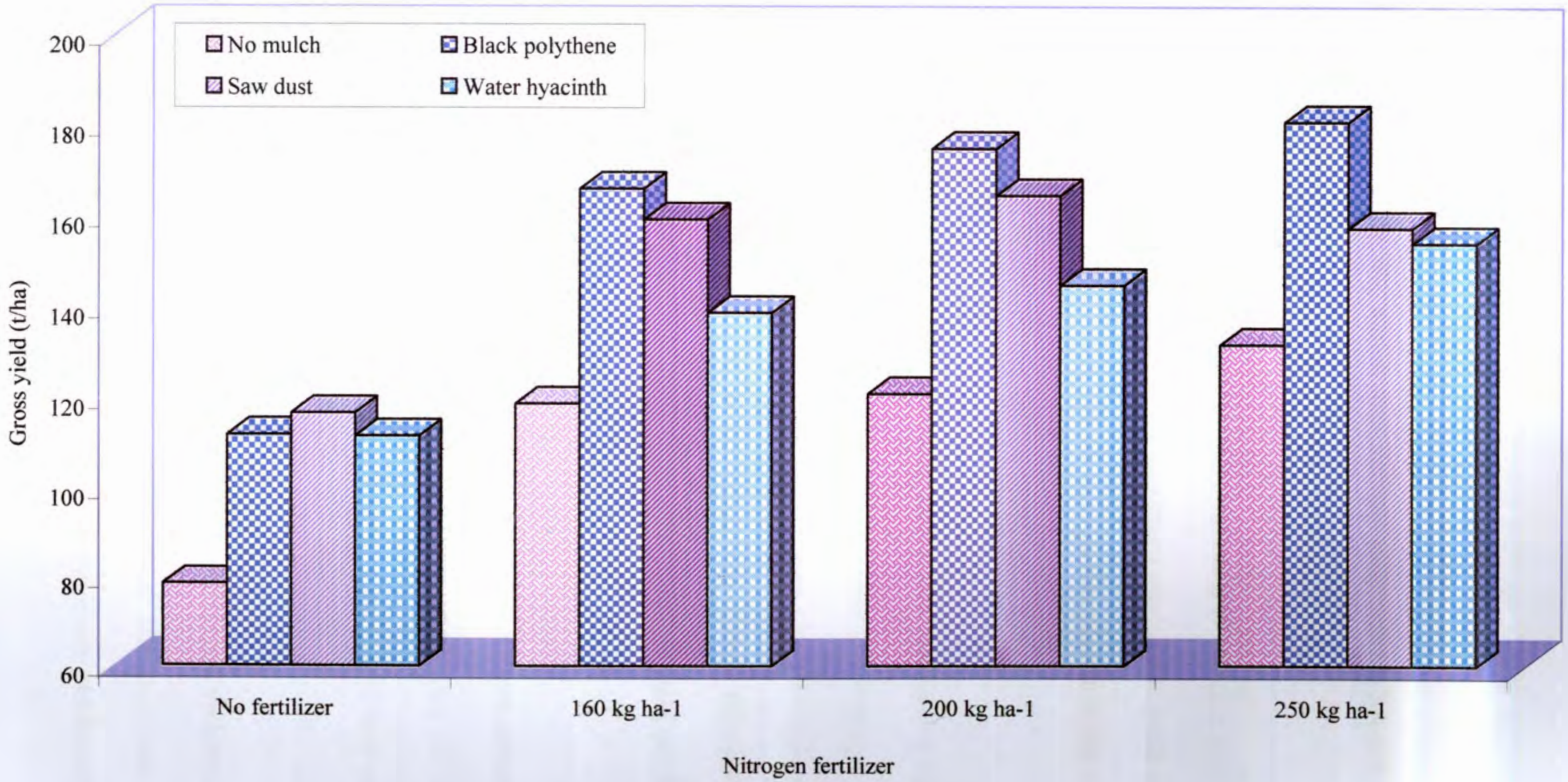


Figure 12. Interaction effect between nitrogen fertilizer and mulches on gross yield in Chinese cabbage

The highest marketable yield per plot of Chinese cabbage (36.98 kg) was recorded in M_1 which was closely followed by M_2 (33.30 kg). On the other hand the lowest marketable yield (22.95 kg) was recorded in M_0 which was closely followed by M_3 (28.47 kg). Generally highest gross yield ensure the highest marketable yield (Table 6).

Marketable yield per plot showed no statistically variation in relation with interaction effect between nitrogen fertilizer and mulches. The maximum marketable yield per plot (43.40 kg) was recorded in N_3M_1 and the minimum (13.68 kg) was recorded in N_0M_0 (Table 7).

4.22 Marketable yield per hectare

Marketable yield per hectare showed statistically significant differences with different doses of nitrogen fertilizer applied in the present experiment. Nitrogen fertilizer showed a gradual increasing tendency to marketable yield per hectare (Figure 13). The highest marketable yield per hectare (120.06 ton) was recorded in N_3 which was closely followed with N_2 and N_1 (110.65 and 107.09 ton). On another way the lowest marketable yield per hectare of Chinese cabbage (67.90 ton) was recorded in N_0.

Marketable yield per hectare at different mulches showed significant difference. The highest marketable yield per hectare (123.27 ton) was recorded in M_1 (Figure 14) which was closely followed by M_2 (111.01 ton) and the lowest marketable yield (76.51 ton) was recorded in M_0 which was closely followed by M_3 (94.91 ton).

Marketable yield per hectare showed no statistically significant variation in relation with interaction effect between nitrogen fertilizer and mulches. The maximum marketable yield per hectare (144.67 ton) was recorded in N_3M_1 and the minimum (45.60 ton) was recorded in N_0M_0 (Figure 15).

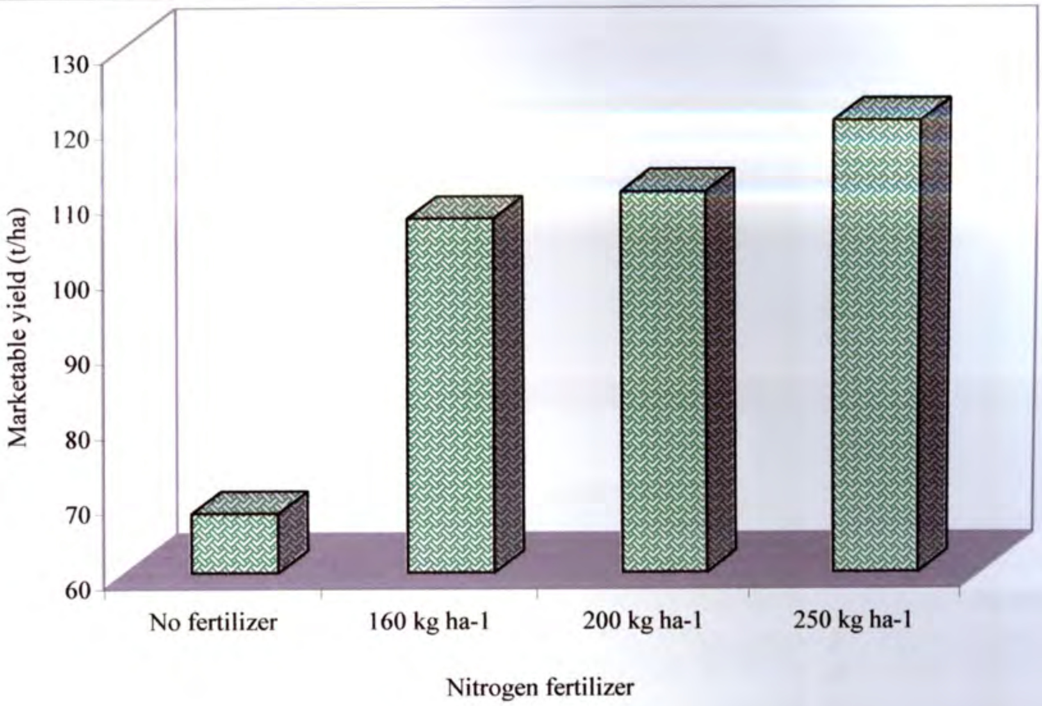


Figure 13. Effect of different level of nitrogen fertilizer on marketable yield in Chinese cabbage

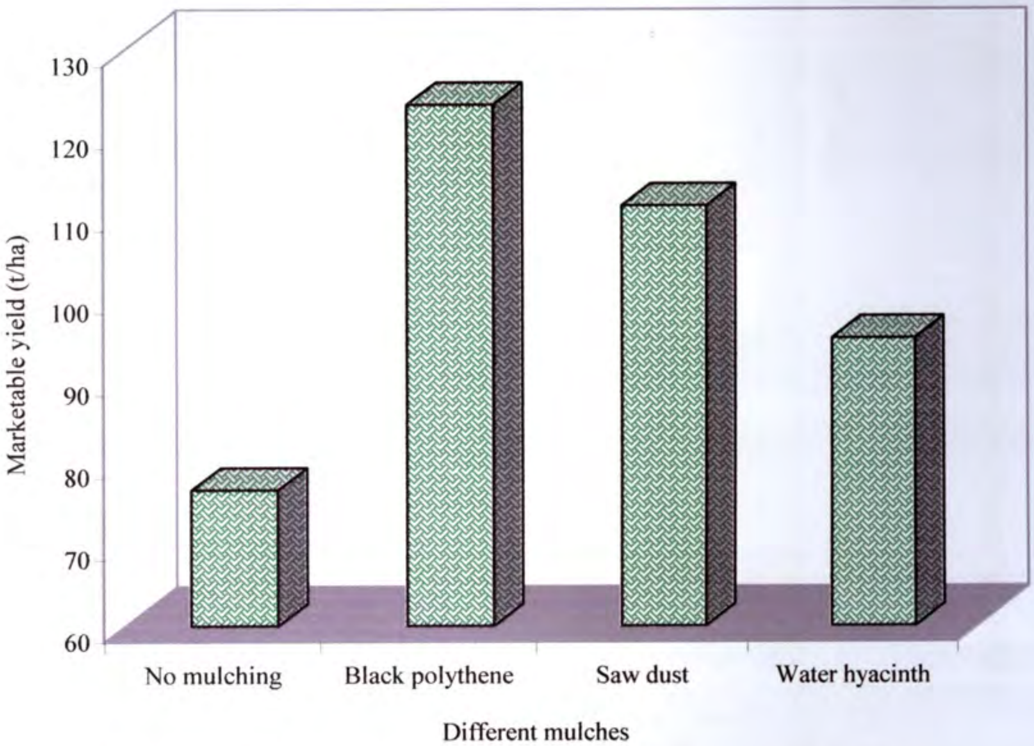


Figure 14. Effect of different mulches on marketable yield in Chinese cabbage

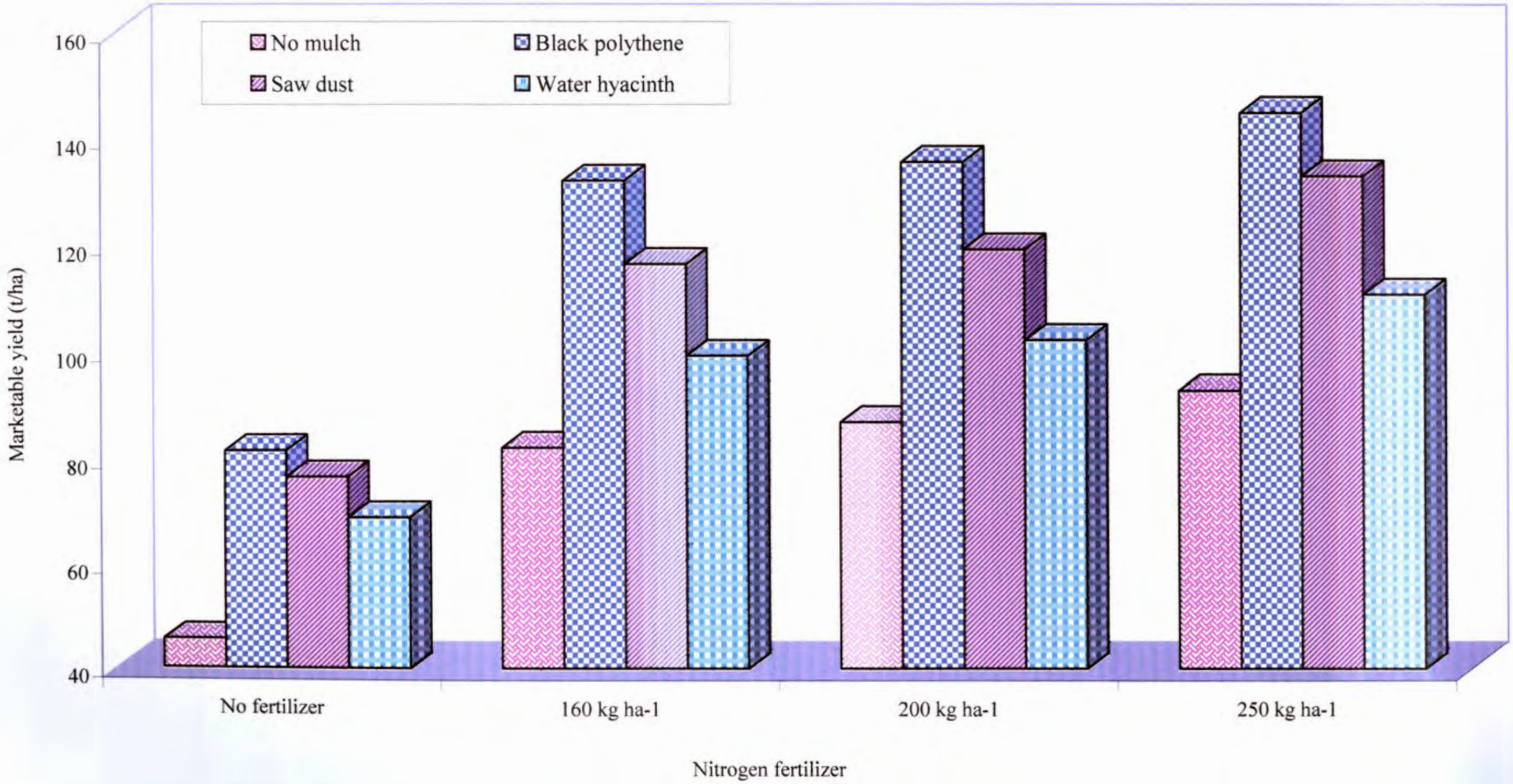


Figure 15. Interaction effect between nitrogen fertilizer and mulches on marketable yield in Chinese cabbage

4.23 Harvest Index

Nitrogen fertilizer showed statistically significant differences in consideration of harvest index in the present trial. The highest harvest index (76.59) was recorded in N_3 which was statistically similar with N_2 and N_1 (73.23 and 73.04, respectively). On the other hand the lowest harvest index (64.53) was recorded in N_0.

Different mulches showed statistically significant variation in the present trial in respect of harvest index. The highest harvest index (77.60) was recorded in M_1 (Table 6) which was closely followed by M_2 (73.86). On the other hand the lowest harvest index (67.08) was recorded in M_0 which was statistically identical with M_3 (68.85).

Interaction effect between nitrogen fertilizers and mulches showed no statistically significant difference in consideration of harvest index. The highest harvest index (84.38) was recorded in N_3M_2 (Table 7) and the lowest harvest index (57.77) was recorded in N_0M_0.

4.24 Economic analysis

The economic analysis was done to find out the gross and net return and the benefit cost ratio in the present experiment and presented under the following headings-

4.4.1 Gross return

In the combination of different doses of nitrogen fertilizer and different mulches highest gross return (Tk. 723,350) was obtained from the treatment combination of N_3M_1 and the second highest gross return (Tk. 677,050) was obtained in N_2M_2. The lowest gross return (Tk. 228,000) was obtained in N_0M_0.

4.4.2 Net return

In case of net return different treatment combination showed different types of net return. In the combination of different doses of nitrogen fertilizer and different mulches highest net return (Tk. 519,929) was obtained from the treatment combination N_3M_1 and the second highest net return (Tk. 474,050) was obtained in N_2M_1. The lowest net return (Tk. 40,404) was obtained in N_0M_0.

4.4.3 Benefit cost ratio

In the combination of different doses of nitrogen fertilizer and different mulches highest benefit cost ratio (3.56) was attained from the treatment combination of N_3M_1 and the second highest benefit cost ratio (3.34) was acquired in N_2M_1. The lowest befit cost ratio (1.22) was obtained in N_0M_0 (Table 8).

Table 8. **Cost and return of Chinese cabbage cultivation as influenced by nitrogen fertilizer and mulching**

Treatment Combination	Cost of production (Tk./ha)	Yield of Chinese cabbage	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
N_0M_0	187596	45.60	228000	40404	1.22
N_0M_1	200112	81.21	406050	205938	2.03
N_0M_2	198427	76.23	381150	182723	1.92
N_0M_3	194215	68.56	342800	148585	1.77
N_1M_0	190147	81.62	408100	217953	2.15
N_1M_1	202663	131.80	659000	456337	3.25
N_1M_2	200978	116.11	580550	379572	2.89
N_1M_3	196766	98.83	494150	297384	2.51
N_2M_0	190484	86.47	432350	241866	2.27
N_2M_1	203000	135.41	677050	474050	3.34
N_2M_2	201315	118.90	594500	393185	2.95
N_2M_3	197103	101.82	509100	311997	2.58
N_3M_0	190905	92.36	461800	270895	2.42
N_3M_1	203421	**144.67**	**723350**	**519929**	**3.56**
N_3M_2	201736	132.78	663900	462164	3.29
N_3M_3	197524	110.44	552200	354676	2.80

Nitrogenous fertilizer
For N_0 : 0 kg N/ha
For N_1 : 160 kg N/ha
For N_2 : 200 kg N/ha
For N_3 : 250 kg N/ha

Mulching
For M_0 : No mulch/control
For M_1 : Black polythene
For M_2 : Saw dust
For M_3 : Water hyacinth

Market price of Chinese cabbage @ Tk. 5,000/t
Gross return = Total yield (t/ha) × Tk. 5,000
Net return = Gross return - Total cost of production
Benefit Cost Ratio (BCR) = Gross return/Total cost of production

Chapter ٥

SUMMARY AND CONCLUSION

Chapter V

SUMMARY AND CONCLUSION

A field experiment was conducted in the experimental Horticulture Farm Field Laboratory of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2005 to December 2006 to study the effect of different levels of nitrogen and mulching on growth and yield of Chinese cabbage. The experiment considered of two factors. Factor A: Levels of nitrogen fertilizer (4 levels) i.e. N_0 (No N fertilizer/Control), N_1 (160 kg/ha), N_2 (200 kg/ha) and N_3 (250 kg/ha); Factor B: Mulches (4 levels): M_0 (No mulching), M_1 (black polythene), M_2 (saw dust) and M_3 (water hyacinth). There were on the whole 16 (4×4) treatments combinations. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. After emergence of seedlings, various intercultural operations were accomplished for better growth and development of the Chinese cabbage seedlings. Data were collected in respect of the plant growth characters and yield of Chinese cabbage. The data obtained for different characters were statistically analyzed to find out the significance of the difference levels of N fertilizers and mulches on yield and yield contributing characters of Chinese cabbage.

A statistically significant variation was recorded in respect of all of the recorded characters in relation with different doses of nitrogenous fertilizer. The tallest Chinese cabbage plant (43.12 cm) during harvesting period was recorded in N_3 and the shortest (36.15 cm) was recorded in N_0. At harvest the highest spread of Chinese cabbage plant (64.43 cm) was recorded in N_3 and the lowest spread (48.38 cm) was recorded in N_0. The lowest number of loose leaves (12.45) was recorded in the plot with N_3 and the highest number of loose leaves for Chinese cabbage (14.60) during harvesting was reported in N_0. The highest number of roots per plant of Chinese cabbage (27.38) was recorded in N_3 and the minimum number of roots per plant of Chinese cabbage (21.88) was recorded in N_0. The highest length of roots per plant (26.88 cm) was recorded in N_3 and the lowest length of roots per plant (20.37 cm) was recorded in N_0. The maximum fresh and dry weight of roots (17.39 g and 2.49 g) was recorded in N_3 and the minimum fresh and dry weight of roots per plant (12.37 g and 2.19 g) was reported in N_0. The highest number of unfolded leaves per plant of (15.23) was recorded in N_0 and the minimum number (11.68) was recorded in N_3 on the other hand the highest number of folded leaves (55.51) was recorded in N_3 and the lowest number (42.96) was reported in N_0. The longest duration to start head formation (46.80) was recorded in N_0 and the shortest (40.96) was recorded in N_3 on the other hand the highest days to head maturity (27.45) was recorded in N_0 and the lowest days to head maturity (25.32) was recorded in N_3. The maximum thickness and diameter of head (25.18 and 17.06 cm) of Chinese cabbage was recorded in N_3 and the minimum thickness and diameter of head (18.98 and 14.21 cm) was recorded in N_0. The highest fresh and dry weight of head (2.43 kg and 15.30 g) was recorded in N_3 on the other hand the lowest fresh and dry weight (1.57 kg and 10.42 g) was recorded in N_0. The highest marketable yield per plot and hectare of Chinese cabbage (36.02 kg and 120.06 ton) was recorded in N_3 and the lowest yield (20.37 kg and 67.90 ton) was recorded in N_0.

The highest Chinese cabbage plant, spread of plant (44.50 cm, 58.28 cm) during harvest period was recorded in M_1 and the shortest plant and spread of plant (37.60 cm and 49.58 cm) was recorded in M_0. The minimum number of loose leaves for Chinese cabbage plant (11.75) during harvest was recorded in M_1 and the highest number of loose leaves of Chinese cabbage plant (14.97) was recorded in M_1. The highest number and length of roots per plant of Chinese cabbage (26.41 and 26.92 cm) during harvesting was recorded in M_1 and the lowest number and length of roots per plant (23.37 and 22.16 cm) was recorded in M_0. The maximum fresh and dry weight of roots (17.08 and 2.52 g) was recorded in M_1 and the minimum fresh and dry weight of roots per plant (13.40 and 2.22 g) was recorded in the plot in M_0. The maximum number of folded leaves for Chinese cabbage plant (54.47) was recorded in M_1 and the minimum number of folded leaves of Chinese cabbage plant (46.82) was recorded in M_0. The highest days to start of head formation of Chinese cabbage (45.37) was recorded in M_0 and the lowest days (41.17) were recorded in M_1. The highest days to head maturity (27.05) was recorded in M_0 and the lowest days (25.71) were recorded in M_1. The maximum thickness and diameter of head of Chinese cabbage (24.74 and 16.86 cm) was recorded in M_1 and the minimum thickness and diameter of head (18.98 and 15.10 cm) was recorded in M_0. The highest fresh and dry weight of head/plant of Chinese cabbage (2.44 kg and 15.64 g) was recorded in M_1 and the lowest fresh and dry weight of head (1.72 kg and 12.24 g) was recorded in M_0. The highest marketable yield per plot and hectare of Chinese cabbage (36.98 kg and 123.27 ton) was recorded in M_1 and the lowest yield (22.95 kg and 76.51 ton) was recorded in M_0.

Interaction effect between nitrogenous fertilizer and mulches demonstrated no significant differences expect 40 DAS for plant height, 20 DAS for number of loose leaves, stem length, folded leaves per plant, thickness of head in Chinese cabbage in the present trail. But in and every case maximum growth and yield contributing characters and yield was observed in N_3M_1 and the reverse result was recorded in N_0M_0.

In the combination of different doses of nitrogenous fertilizer and different mulches highest benefit cost ratio (3.56) was attained from the treatment combination N_3M_1 and the lowest befit cost ratio (1.22) was obtained in N_0M_0.

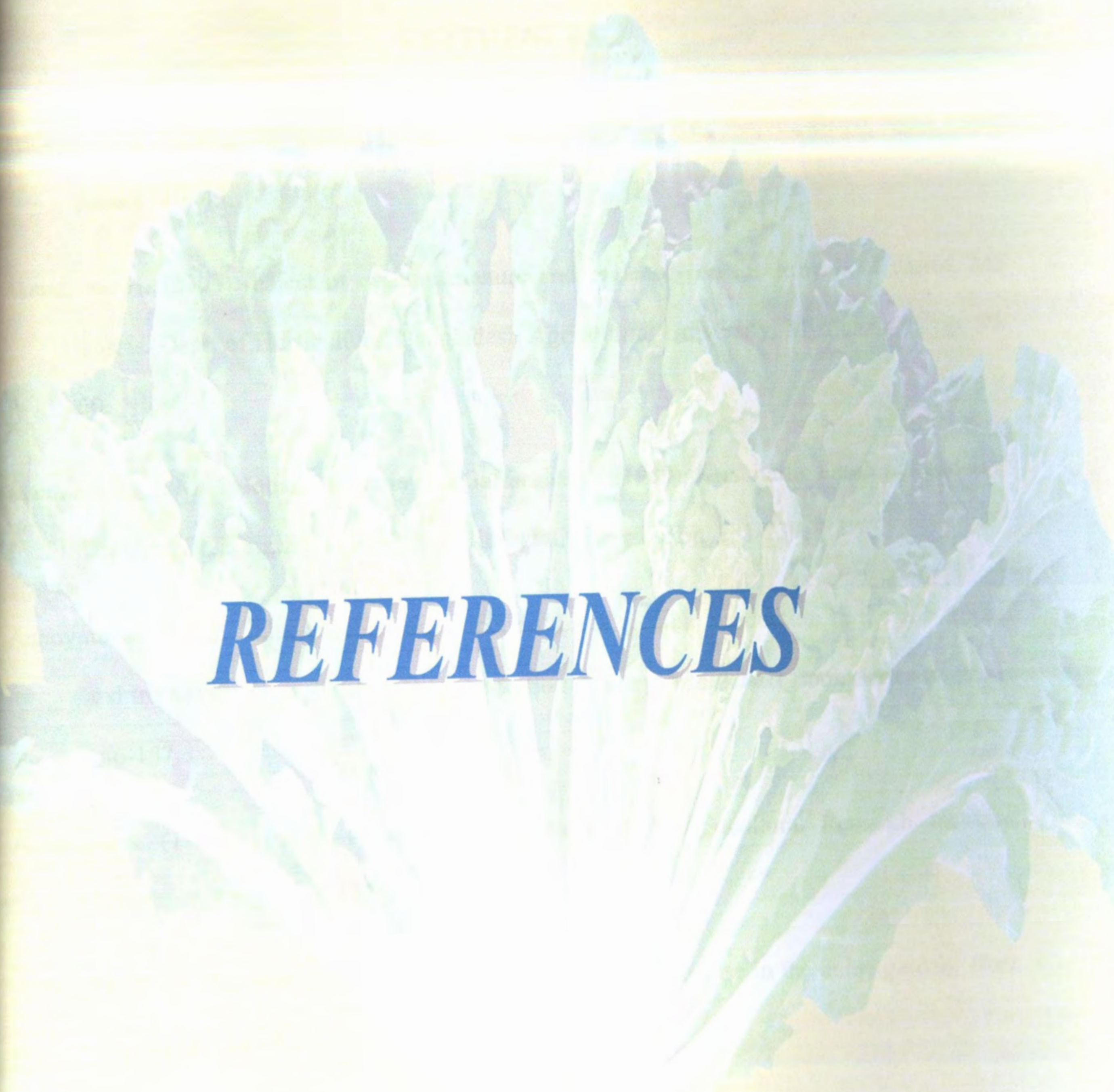
Therefore, it was clear that higher production of Chinese cabbage is possible by using suitable mulches and optimum doses of nitrogen. Under the present condition 250 kg N ha^{-1} and black polythene mulch was the best in consideration of yield and yield contributing characters.

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

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.

2. Another level of nitrogen fertilizer may be included in the further study.

3. Experiment may be carried out with naturally available mulching materials such as rice straw, green leaves, assam lata, satty leaves (*Curcuma amada*) and banana leaves etc.



REFERENCES

REFERENCES

Acharya, B. C. (1988). Effect of mulching on vegetables. Proc. Res. Found., Behar Agril. Coll., Sabour, 10: 49.

Akand, M. H. (2003). Effect of organic manure and mulching on the growth of carrot. MS Thesis. Dept. of Horticulture. Bangladesh Agricultural University, Mymensingh. pp. 59-60.

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

Anonymous. (1972). Chinese cabbage production. In: Vegetable production in the sub-tropics and tropics overseas, Technical Co-operation Agency Japan. Text Book Series N. 25. p. 146-157.

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

Ashworth, S and Harrison, H. (1983). Evaluation of mulches for use in the home garden. *Hort. Sci.*, **18 (2)**: 180-182.

Batsei, S. I., A. A. Polyakov and Nedel, R. F. (1979). Effect of organic and mineral fertilizers on the yield and quality of irrigated late white cabbage in the steppe region of the erimea. Khimiya V. Sel. Skon Khozyistve, **17 (3)**: 18-20 [Cited from Hort. Abstr., 49 (11): 8487-1979].

BBS. (2005). Monthly Statistical Bulletin of the Bangladesh Bureau of Statistics (August). Administration and MIS Wing, Bangladesh Secretariat, Dhaka. p. 280.

Benoit, F. and Ceustermans, N. (1990). Direct covering (DC) and soil mulching of Chinese cabbage (*Brassica pekinensis* Rubr.). Proc. Intl. Cong. on the Use of Plastic Agriculture, New Delhi, India, 26 February to 2 March, 1990.

Bragagnolo, N and Mielriezuk, J. (1990). Soil mulching by wheat straw and its relation to soil temperature and moisture. Revista Brasilerira de Ciencia do Solo, **14 (3)**: 369-373 [Cited from Wheat, Barley and Triticale Abstr., 51 (416), 1992].

Chen, Q., X. Zhang, H. Zhang, P. Christie, Horlacher, D., Liebig, H. P. (2004). Evaluation of current fertilizer practice and soil fertility in vegetable production in the Beijing region. Department of Plant Nutrition, China Agricultural University, 2 Yuanmingyuan West Road, Beijing 100094, China. Nutrient-Cycling-in-Agroecosystems. 2004; 69(1): 51-58

Choi, W., R. HeeMyong and S. X.Chang. (2004). Recovery of fertilizer-derived inorganic-15N in a vegetable field soil as affected by application of an organic amendment. Plant-and-Soil. **263 (1/2)**: 191-201.

Csizinszky, A. A. and D. J. Sehuster. (1985). Response of cabbage to insecticide schedule plant spacing and fertilizer rates. *J. Amer. Soc.* Hort. Sci., **110 (6)**: 888-893.

Ducsay, L and L. Varga. (2003). Cultivation of Brassica pekinensis under different forms of nitrogen nutrition. Zahradnictvi-Horticultural-Science. 2003, 30: 3, 112-115.

Edris, K. M., Islam, A. T. M. T., Chowdhury, M. S. and Haque, 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 of the United Nations. Rome, Italy. 42: 190-193.

Farooque, A. M. and Mondal, M. F. (1987). Effects of spacing and levels of nitrogen on growth and yield of cabbage. *Bangladesh Hort.*, **15 (2)**: 1-6.

Gattorsen, G. (1992). Effect of various types of plastic film on temperature and vegetable yield. Norsk Land Bruksforsking, **6 (1)**: 51-60 [Cited from Hort. Abstr., 60 (2): 2471, 1991].

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.

Gunadi, N. and Asandhi, A. A. (1989). The effect of nitrogen and mulch on cabbage in low land area. Bull. Penelition Hort., **17 (3)**: 99-107 [Cited from Hort. Abstr., 60 (10): 8072-1990].

Hembry, J. K., Davies, J. S., Banik, L. and Rumpel, J. (1994). Using mulches for weed control and preventing leaching of nitrogen fertilizer. Acta Hort., 371: 311-316.

Hill, D. E., L. Hankin and Stephens, G. R. (1982). Mulches: their effect on fruit timing and yields of vegetables. Bull. Con. Agric. Expt. Sta., New Haven.

Hossain, M. E. (1999). Effect of different sources of nutrients and mulching on the growth and yield of cabbage. MS Thesis, Dept. Hort., Bangladesh Agricultural University, Mymensingh, Bangladesh. pp. 29-68.

Jaenaksorn, T. and Ikeda, H. (2004). Possibility of substituting soil less fertilizer with soil fertilizer for growing leafy vegetables in hydroponics. Acta-Hort., 644: 351-357.

Jaiswal, J. P., Subedi, P. P. and Bhattarai, S. P. (1997). Mulching trial on carrot, fertilizer trial on radish and top-dressing trial on Chinese cabbage conducted during 1995/96. Working-Paper -Lumle-Regional-Agricultural-Research-Centre. 1997, No. 97-27.

Kalisz, A. and Cebula, S. (2001). Effect of direct plant covering and soil mulching in the spring production of some Chinese cabbage cultivars. Folia Hort., **13 (2)** : 3-12.

Khadir, G. A., Marazat, S. K. and Sadoun, S. A. (1989). Effect of different levels of urea fertilizer and plant spacing on growth and yield of cabbage. Dirasat, **16 (9)**: 88-105.

Krezel, J. and Koota, E. (2004). The effect of nitrogen fertilization on yield and biological value of Chinese cabbage grown from seed sowing for autumn harvest. Katedra Ogrodnictwa, Akademia Rolnicza, ul. Rozbrat 7, 51-334 Wrocaw, Poland. Folia-Universitatis-Agriculturae-Stetinensis,-Agricultura. 2004; (95): 197-200

Lal M. H. (1989). Effect of mulching on Chinese cabbage. Acta-Agriculturae-Scandinavica.-Section-B,-Soil-and-Plant-Science. 1990, **12**: 1, 12-13.

Lawande, K. E., Bhore, D. P., Kale, P. N. and Patil, J. D. (1986). Effects of spacing, nitrogen, phosphrous and potassium on yield and yield contributing characters of cabbage. *J. Maharashtra Agril.* Univ., **11 (2)**: 192-196.

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

Liu,Y., Cao, Y., Xia, J., Wu, J., Liu, J., Cao, Y., Xia, J. and Wu, J. (1999). Effect of different ratios of NPK combination on yield and nitrate accumulation of Chinese cabbage. Department of Plant Nutrients, China Agricultural University, Beijing 100094, China. Soils-and-Fertilizers-Beijing. 1999, No. 4, 26-29; 9 ref.

Magnusson, M. (2002). Mineral fertilizers and green mulch in Chinese cabbage [Brassica pekinensis (Lour.) Rupr.]: effect on nutrient uptake, yield and internal tipburn. Acta-Agriculturae-Scandinavica.-Section-B,-Soil-and-Plant-Science. 2002, 52: 1, 25-35.

0breza, T. A. and Vavrina, C. S. (1993). Production of Chinese cabbage in relation to nitrogen Source, Rate and Leaf nutrient concentration in Soil Science and Plant Analysis. 24: 13-14 [Cited from Hort. Abstr., 1994, **64 (4)**: 2751].

Oh, D. G., Yoon, J. Y., Lee, S. S. and Woo, J. G. (1984). The effect of some mulch on Chinese cabbage growing different seasons. *J. Korean Soc. Hort. Sci.*, **25 (4)**: 265-269.

Opena, R. T., Kuo, C. C. and Yoon, J. Y. (1988). Breeding and Seed Production of Chinese cabbage in the Tropics and Subtropics. Tech. Bul., 17, AVRDC. p. 97.

Oyabu, T. I., Suzuki and Aougi, M. (1988). Effects shading materials and mulching film on the yield and quality of summer and winter crops of chin guentsai (*Brassica campestries* L. Chinese group). Res. Bull. Japan Agric. Res. Cent., 1146: 1029-1034 [Cited from Hort. Abstr., 60 (4): 74, 1990].

Poll, J. T. K. and Gaven, C. G. N. (1996). Effect of mulches on the yield and quality of green vegetables. Rerslag- Proefstation-roor-de-Akkerbouwen-de-groefetealt-in-de-vollegmnd, 212: 87 [Cited from Hort. Abstr., 68 (9): 7769, 1998].

Qian, X., J. Wang, Y. Bai, F. Ding, Z. Zou, Z. Zhou, Z. Chen And Xie, T. (2003). Effects of IFC-microelement fertilizer on yield and nitrate accumulation of Chinese cabbage. Department of Agronomy, Agricultural College of Yangzhou University, Yangzhou 225009, China. Rural-Eco-Environment. 2003; **19(2)**: 29-33.

Rahman, M. A., Guha, D., Golder, P. C. and Satter, M. A. (1989). Effect of irrigation and mulch on the growth and yield of cabbage in the hilly region. Bangladesh Hort., **17 (1)**: 37-39.

Ram, K. and Sharma. P. K. (1969). Effect of nitrogen supply on growth, yield and ascorbic acid content of cabbage, Poona Agril. Coll. Ma., 59: 25-29 [Cited from Hort. Abstr., 40 (3): 6119, 1970].

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

Roy, A. K., Muhshi, A. A. A. and Khan, A. H. (1990). Effect of different mulches on the growth of potato. *Bangladesh J. Bot.*, **19 (1)**: 41-46.

Russo, V., Cartwright, M. B. and Webber, C. L. (1997). Mulching effect on erosion of soil beds and on yield of autumn and spring planted vegetables. Biol. Agril. Hort., **14 (2)**: 85-93 [Cited from Hort. Abstr., 67 (11): 1997].

Saifullah, M., Ahmed, S. U. and Rahman, M. H. (1996). Effect of mulching on the growth and yield of cabbage. Prog. Agric., 7 (1): 15-19.

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

Shamim, M. I. and Kamruzzaman, N. K. (2004). Effect of mulching and nitrogen fertilizer on growth and yield of Chinese cabbage. Hort. Sci., **45 (2)**: 57-69.

Subhan. (1989). The effect of mulching and timing of nitrogen application on the growth and yield of cabbage cultivar K-K-cross in a low land area. Bull. Peletition Hort., **17 (3)**: 53-62 [Cited from Hort. Abstr., 59 (9): 7393, 1989].

Sweeney, D. W., Graetz, D. A., Bottehers, A. B., Locasio, S. J. and Campbel, K. L. (1987). Tomato yield and nitrogen recovery as influence by irrigation method, nitrogen source and mulch. Hort. Sci., **22 (1)**: 27-29.

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

Thompson, H. C. and Kelly, W. C. (1957). Cole Crops. In: Vegetable Crops McGraw Hill Book Co. New York. pp. 15, 280-281, 370.

Tindall, H. D. (1983). Vegetable in the Tropics. Macmillan Education Ltd. Houndmills. Basingstoke Hampshiire. RhRI 2 × S and London [Cited from Hort. Abstr., 50 (6): 3791-1984].

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

Vleck, F. and J. Polack. (1977). Effect of spacing and fertilizer rates on cabbage yield and head weight. Proc. Florida State Hort. Soc., 89: 118-120 [Cited from Hort. Abstr., 48 (1): 392, 1978].

Wang, Z. H. Li, B. Li, X. Ye, P. Sun, H. Dai, T. Xiang, Wang, Z. Y. (2003). Influence of nitrogen rates, soil fertility and harvest time on nitrate in Chinese cabbage. College of Resources and Environmental Sciences, Southwest Agricultural University, Chongqing 400716, China. Scientia-Agricultura-Sinica. 2003, 36: 9, 1057-1064.

Warner, J. Cerkauskas, R. and Zhang, T. (2004). Nitrogen management and cultivar evaluation for controlling petiole spotting and bacterial soft rot of Chinese cabbage. Greenhouse and Processing Crops Research Centre, Harrow, Ontario, Canada. Acta-Horticulturae. 2004; (635): 151-157.

White, J. M. and Forbes, R. B. (1978). Effect of spacing and fertilizer rates on cabbage yield and head weight. Proc. Florida State Hort. Soc., 89: 118-120 [Cited from Hort. Abstr., 48 (1): 392, 1978].

Widjajanto, D. W., Honmura, T. and Miyauchi, N. (2003). Possible utilization of water hyacinth (Eichhornia crassipes (Mart.) Solms), an aquatic weed, as green manure in vegetables cropping systems. *Japanese-Journal-of-Tropical-Agriculture*. 2003, **47**: 1, 27-33.

Ye, J., C. Wu, L. Shen, X. Zhang, G. Zhang and Song, S. (2004). Effect of the combined application of organic manure and fertilizer on Chinese cabbage yield and quality. Journal-of-Jilin-Agricultural-University. 2004; **26(2)**: 155-157, 161

Yoon, J. Y., D. G. Oh., J. G. Woo and Lee, S. S. (1984). Effect of some mulch materials on Chinese cabbage growing in different seasons. *J Korean Soc. Hort. Sci.*, **25 (4)**: 263-269.

Yoshizawa, T. C. H. M and Roan, Y. C. (1981). Management of Summer Chinese cabbage in Taiwan Chinese cabbage. AVRDC, Shanhua, Taiwan. p. 125.

Zhang, Y., Q. Shen, J. Yu, L. Sun, H. Liu, Q. Li, H. Xin, Wang, Z. (2004). Effects of application of nitrogen fertilizers of different N forms on yields and quality of Chinese cabbage. Research Center of Agricultural Resources and Environments, Jiangsu Academy of Agricultural Sciences, Nanjing 210014, China. *Jiangsu-Journal-of-Agricultural-Sciences*. 2004**; 20(3)**: 184-188

APPENDICES

APPENDICES

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

Mechanical analysis

Constituents	Percent
Sand	33.50
Silt	60.20
Clay	6.20
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.08
Organic carbon (%)	1.3
Total nitrogen (%)	0.08
Available P (ppm)	20
Exchangeable K (%)	0.2

Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October to December 2005

Month	Air temperature (^0C)			RH (%)	Total rainfall	Sunshine
	Maximum	Minimum	Mean	9 am	(mm)	(hrs/day)
October 05	30.97	23.31	27.14	75.25	208	208.9
November 05	29.45	18.63	24.04	69.52	00	233.2
December 05	26.85	16.23	21.54	70.61	00	210.5

Appendix III. Analysis of variance of the data of plant height, spread of plants and number of loose leaves per plant of Chinese cabbage as influenced by different level of nitrogen and mulching

Sources of variation	Degrees of freedom	Mean square			
		Plant height			
		20 DAS	30 DAS	40 DAS	At harvest
Replication	2	12.054	10.751	0.013	1.544
Factor A (N levels)	3	126.301**	138.289**	91.019**	120.177**
Factor B (Mulching)	3	60.699**	51.497**	74.253**	101.802**
Interaction (A × B)	9	2.508	3.050	10.911	12.479**
Error	30	2.592	4.430	3.657	3.432

** : Significant at 0.01 level of significance

Appendix III. Contd.

Sources of variation	Degrees of freedom	Mean square			
		Spread of plant (cm) at			
		20 DAS	30 DAS	40 DAS	At harvest
Replication	2	0.863	4.437	0.746	5.469
Factor A (N levels)	3	242.428**	316.683**	562.159**	587.487**
Factor B (Mulching)	3	101.392**	135.041**	169.357**	200.777**
Interaction (A × B)	9	3.864	1.958	1.339	1.553
Error	30	3.289	6.390	5.344	7.144

** : Significant at 0.01 level of significance

Appendix III. Contd.

Sources of variation	Degrees of freedom	Mean square			
		Number of loose leaves/plant at			
		20 DAS	30 DAS	40 DAS	At harvest
Replication	2	0.111	3.676	5.684	8.382
Factor A (N levels)	3	8.205**	10.396**	8.480**	9.703**
Factor B (Mulching)	3	2.541**	20.661**	22.838**	27.480**
Interaction (A × B)	9	0.457**	1.171	1.280	1.701
Error	30	0.098	1.908	0.976	1.747

** : Significant at 0.05 level of significance

Appendix IV. Analysis of variance of the data on yield contributing characters of Chinese cabbage as influenced by different level of nitrogen and mulching

Sources of variation	Degrees of freedom	Mean square			
		Roots/ plant (No.)	Root length (cm)	Fresh weight of roots/ plant	Dry weight of roots /plant
Replication	2	0.997	0.194	2.481	0.012
Factor A (N levels)	3	64.028**	103.931**	55.058**	0.203**
Factor B (Mulching)	3	26.255*	47.669**	31.703**	0.184**
Interaction (A × B)	9	4.474	29.700	1.027	0.005
Error	30	8.170	4.276	1.462	0.030

** : Significant at 0.01 level of significance

Appendix IV. Contd.

Sources of variation	Degrees of freedom	Mean square			
		Stem length (cm)	Folded leaves/ plant (No.)	Unfolded leaves/ plant (No.)	Wt. unfolded leaves/ plant (g)
Replication	2	0.053	7.916	4.087	55.079
Factor A (N levels)	3	1.254**	357.037**	26.304**	23590.163**
Factor B (Mulching)	3	1.344**	128.062**	17.372**	16170.009**
Interaction (A × B)	9	0.430**	25.678**	0.874	482.697
Error	30	0.081	5.806	1.011	237.390

** : Significant at 0.05 level of significance

Appendix IV. Contd.

Sources of variation	Degrees of freedom	Mean square		
		Days to initiation of head	Thickness of head (cm)	Diameter of head (cm)
Replication	2	0.766	6.833	1.750
Factor A (N levels)	3	86.521**	89.270**	18.497**
Factor B (Mulching)	3	43.033**	32.718**	7.649**
Interaction (A × B)	9	3.561	7.197**	0.613
Error	30	4.306	2.188	1.583

** : Significant at 0.05 level of significance

Appendix V. **Analysis of variance of the data on yield contributing characters and yield of Chinese cabbage as influenced by different level of nitrogen and mulching**

Sources of variation	Degrees of freedom	Mean square			
		Head volume	Days to head maturity	Fresh weight of head (Kg)	Dry weight of head (g)
Replication	2	2687.220	3.165	0.005	1.520
Factor A (N levels)	3	2554173.472**	9.981**	1.691**	58.629**
Factor B (Mulching)	3	1883891.298**	4.751**	1.206**	31.936**
Interaction (A × B)	9	49785.436	0.766	0.040	0.975
Error	30	33038.199	2.327	0.035	1.066

** : Significant at 0.05 level of significance

Appendix V. Contd.

Sources of variation	Degrees of freedom	Mean square				
		Gross yield (Kg/plot)	Marketable yield (kg/plot)	Gross yield (t/ha)	Marketable yield (t/ha)	Harvest Index
Replication	2	0.288	3.199	3.201	35.540	16.801
Factor A (N levels)	3	599.087**	571.839**	6656.526**	6353.768**	317.503**
Factor B (Mulching)	3	428.494**	443.586**	4761.040**	4928.738**	275.107**
Interaction (A × B)	9	13.240	5.866	147.115	65.173	28.279
Error	30	6.478	3.695	71.983	41.051	36.895

** : Significant at 0.05 level of significance

Appendix VI. Production cost of Chinese cabbage per hectare

A. Input cost

Treatment Combination	Labour cost	Ploughing cost	Seed Cost	Water for seedling Establishment	Bamboo and chati	Mulch Materials	Manure and fertilizers				Insecticide/ pesticides	Sub Total (A)
							Cowdung	Urea	TSP	MP		
N_0M_0	16000.00	9000.00	8500.00	4500.00	5000.00	0.00	30000.00	0.00	1875.00	1980.00	10000.00	86855.00
N_0M_1	18000.00	9000.00	8500.00	4500.00	5000.00	8400.00	30000.00	0.00	1875.00	1980.00	10000.00	97255.00
N_0M_2	19000.00	9000.00	8500.00	4500.00	5000.00	6000.00	30000.00	0.00	1875.00	1980.00	10000.00	95855.00
N_0M_3	19000.00	9000.00	8500.00	4500.00	5000.00	2500.00	30000.00	0.00	1875.00	1980.00	10000.00	92355.00
N_1M_0	17000.00	9000.00	8500.00	4500.00	5000.00	0.00	30000.00	1120.00	1875.00	1980.00	10000.00	88975.00
N_1M_1	19000.00	9000.00	8500.00	4500.00	5000.00	8400.00	30000.00	1120.00	1875.00	1980.00	10000.00	99375.00
N_1M_2	20000.00	9000.00	8500.00	4500.00	5000.00	6000.00	30000.00	1120.00	1875.00	1980.00	10000.00	97975.00
N_1M_3	20000.00	9000.00	8500.00	4500.00	5000.00	2500.00	30000.00	1120.00	1875.00	1980.00	10000.00	94475.00
N_2M_0	17000.00	9000.00	8500.00	4500.00	5000.00	0.00	30000.00	1400.00	1875.00	1980.00	10000.00	89255.00
N_2M_1	19000.00	9000.00	8500.00	4500.00	5000.00	8400.00	30000.00	1400.00	1875.00	1980.00	10000.00	99655.00
N_2M_2	20000.00	9000.00	8500.00	4500.00	5000.00	6000.00	30000.00	1400.00	1875.00	1980.00	10000.00	98255.00
N_2M_3	20000.00	9000.00	8500.00	4500.00	5000.00	2500.00	30000.00	1400.00	1875.00	1980.00	10000.00	94755.00
N_3M_0	17000.00	9000.00	8500.00	4500.00	5000.00	0.00	30000.00	1750.00	1875.00	1980.00	10000.00	89605.00
N_3M_1	19000.00	9000.00	8500.00	4500.00	5000.00	8400.00	30000.00	1750.00	1875.00	1980.00	10000.00	100005.00
N_3M_2	20000.00	9000.00	8500.00	4500.00	5000.00	6000.00	30000.00	1750.00	1875.00	1980.00	10000.00	98605.00
N_3M_3	20000.00	9000.00	8500.00	4500.00	5000.00	2500.00	30000.00	1750.00	1875.00	1980.00	10000.00	95105.00

Cowdung : 10 t/ha
TSP : 125 kg/ha
MP : 165 kg/ha

Nitrogenous fertilizer
For N0 : 0 kg N/ha
For N1 : 160 kg N/ha
For N2 : 200 kg N/ha
For N1 : 250 kg N/ha

Mulching
For M0 : No mulch/control
For M1 : Black polythene
For M2 : Saw dust
For M3 : Water hyacinth

Seed 650 g @ Tk. 3500/kg; Black polythene 1200 m/ha @ Tk. 7.0/m; Saw dust 120 bag/ha @ Tk. 50/bag, Water hyacinth @ Tk. 2500/ha;
Urea @ Tk. 7/ka; TSP @ Tk. 15/kg; MP @ Tk. 12 kg/ha; Labour cost @ Tk. 70/day

Appendix VI. Contd.

B. Overhead cost (Tk./ha)

Treatment Combination	Cost of lease of land for 6 months (13% of value of land Tk. 6,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on 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)]
N_0M_0	78000	11291	11449	100741	187596
N_0M_1	78000	12643	12213	102857	200112
N_0M_2	78000	12461	12111	102572	198427
N_0M_3	78000	12006	11853	101860	194215
N_1M_0	78000	11567	11605	101172	190147
N_1M_1	78000	12919	12369	103288	202663
N_1M_2	78000	12737	12266	103003	200978
N_1M_3	78000	12282	12009	102291	196766
N_2M_0	78000	11603	11626	101229	190484
N_2M_1	78000	12955	12390	103345	203000
N_2M_2	78000	12773	12287	103060	201315
N_2M_3	78000	12318	12030	102348	197103
N_3M_0	78000	11649	11651	101300	190905
N_3M_1	78000	13001	12415	103416	203421
N_3M_2	78000	12819	12313	103131	201736
N_3M_3	78000	12364	12055	102419	197524

<u>Nitrogenous fertilizer</u>

For N_0 : 0 kg N/ha
For N_1 : 160 kg N/ha
For N_2 : 200 kg N/ha
For N_1 : 250 kg N/ha

<u>Mulching</u>

For M_0 : No mulch/control
For M_1 : Black polythene
For M_2 : Saw dust
For M_3 : Water hyacinth