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Response of Head Cabbage (*Brassica oleracea* L.) to Different Rates of Inorganic Nitrogen Fertilizer and Farmyard Manure at Bore, Southern Oromia, Ethiopia

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Abstract

Cabbage (*Brassica oleracea* L.) is the second most important vegetable crop in Ethiopia in area coverage as well as level of production next to red pepper. However, yield of the crop is often constrained by low and imbalanced nutrient supply. This study was conducted at the Bore Agricultural Research Center (BoARC) during the period from July 1, 2014 to December 2, 2014 cropping season to assess the response of N and FYM on growth and yield of cabbage. The treatments consisted of factorial combinations of five levels of N (0, 59, 119, 235 and 294 kg N ha⁻¹) and four levels of FYM (0, 3, 6 and 10 t ha⁻¹) and were laid out in RCBD with three replications. The ANOVA results showed that interaction effect of N and FYM significantly (P<0.001) difference on plant height, number of expanded leaves, days to head initiation, days to 90% maturity, head height, head diameter, untrimmed head weight, trimmed head weight, yield with and without wrapper and biomass of yield. There was a Significance differences between the mean plant heights (43.2cm) of head cabbage observed versus FYM of (10 t ha⁻¹) with each level of N (235 kg ha⁻¹) for plant height. However, the combined effect of highest N (294 kg ha⁻¹) and highest FYM (10 t ha⁻¹) recorded maximum number of leaves (16.66), shortest days to head initiation (63.33) and early days to maturity (112). And also the interaction effect of both N and FYM (235 kg + 6 t ha⁻¹), respectively was highly significantly (P<0.001) recorded highest head height (18.14cm), highest head diameter (17.03cm), highest untrimmed head weight (2296.67g), highest trimmed head weight (1766.67g), maximum (107.47 t ha⁻¹) yield with wrapper head cabbage, highest head yield without wrapper (72.36 t ha⁻¹) and maximum biomass yield (107.47 t ha⁻¹) of head cabbage. There was an increasing trend in the yield without wrapper or marketable head yield parameter with the increasing in the rate till combined application of 235 kg N ha⁻¹ from UREA and 6 t FYM ha⁻¹, but the yield declined above these combinations. Based on partial budget analysis the highest net benefit was obtained from treatment combinations of 235 kg N ha⁻¹ with 6 t ha⁻¹ with a marginal rate of return 2535.31%. The most attractive rates for the producers with low cost of production and higher benefits in this case were treatment combination of 235 kg N ha⁻¹ with 6 t ha⁻¹. Generally results of the study suggested that head cabbage responded well to the combined application of N and FYM and application of 235 kg N ha⁻¹ + 6 t FYM ha⁻¹ can give optimum cabbage head yield in the study area.

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FYM, N, Thomas F1, Trimmed head, Untrimmed head, Yield with wrapper, Yield without wrapper.

Introduction

Cabbage belongs to the member of Brassicaceae family, genus *Brassica* and *Brassica oleracea* L, the progenitor form of cabbage which is believed to have evolved in the Mediterranean area. It was introduced to China more than 2000 years ago, where the heading (*Brassica oleracea* L) types were developed. They contain different amounts of nutrients with savoy type being more superior (Yamaguchi, 2003). Initially cabbage was used for medicinal purposes such as treatment for gout, stomach problems, headaches and deafness, while now it is mainly used as a fresh market crop and for processing. For processing, cabbage can be mixed with other vegetables or sold as stir-fry and for making sauerkraut (Pierce, 2007).

Cabbage is the second most important vegetable crop in Ethiopia both in area coverage as well as level of production next to red pepper, or *Capsicum* species (MoA, 2011). Vegetables accounted only about 1.43% of the area under all crops at national level. However, of the total estimated area under vegetables, 70.89% and 18.07% was under red peppers and head cabbage, respectively (CSA, 2012). In the Gudji Zone, head cabbage is widely cultivated; and the area (ha), production (tons), and yield (ton ha⁻¹) of the crop in *meher* season of 2012/13 was 1703.77, 15678.3 and 9.2, respectively (CSA, 2012). In fact there is no evidenced information on the level of production and marketing of the head cabbage both in the study area and country. Head cabbage is an important cool season crop in highland parts of the zone including Bore. The productivity and market access were high in the area that transported up to the border of the country (Personal observation).

Head cabbage has short stem and a globular head of tightly overlapping green to purplish leaves. As far as their heads are concerned they are compact or loose. It is a biennial crop that is grown as an annual which takes 6-11 weeks from planting to the end of the vegetative stage. Cabbage is a cool season crop which requires adequate availability of soil water and plant nutrients for optimum growth. It has a moderately high frost tolerance. It will grow at 7 °C, but it does best from 15.5- 18 °C, above 27 °C the plants may bolt, causing the heads to split open (Ashworth, 2002). Cabbage seed germinate in about two weeks in soils with temperature as low as 10 °C, which allows for early plantings in cooler regions (Smith, 1995). Depending on the variety, cabbage requires 60 to 100 days from sowing to reach market maturity. A well-

drained sandy loam soil with good organic content and soil pH of between 6.0 and 6.5 is preferred (Yano *et al.*, 1999).

High human and animal population densities in some areas in the highlands of Ethiopia like Gudji have surpassed land carrying capacities escalating environmental degradation. Ethiopia has the highest livestock Resource in Africa. The traditional balance between people, livestock and their habitat and the socio-economic systems is fast disappearing. Hence, achieving sustainable increases of agricultural production has been a priority problem of the country (Wakene *et al.*, 2001).

In order to maintain and improve cabbage production, through agronomic practices some factors have to be considered. Use of integrated nutrient management and correct agricultural practices such as optimum application of nutrients has to be adhered for successful vegetable production (Bulluck *et al.*, 2002). Especially in an area with high livestock resource that was good input for the preparation of manures. Yazachew and Kasahun, (2011) reported that the study area is well known with the livestock resource. Livestock population size of the district was about 1095916 during year 2000.

All agricultural activities are under small-scale peasant holdings. There is no large scale private as well as state farm in the district. The use of modern agricultural inputs is very low, especially inorganic fertilizers for its high cost and poor accessibility. Highland parts of Gudji Zone have humid and sub humid moisture condition, which have longer growing season. Most cereal crops like maize take too long to mature. But vegetable crops like cabbage and Irish potato which are dominantly cultivated by the farmers mature in short growing season, less than four months. Therefore, optimum yields with high quality cabbages can be gained with integration of organic and inorganic fertilizers.

Basically there has been no research carried out on response of cabbage to chemical and organic fertilizer application and recommendations in the country. Cabbage is a heavy nitrogen and potassium feeder. When soils are infertile, higher amounts of nitrogen and potassium should be applied compared to phosphorus for head cabbage (Sorensen, 2003). Experiments done in India showed that treatment combinations with organic and inorganic fertilizers recorded significantly higher cabbage head yield (42.42 t ha⁻¹) over the control with an addition of 150 kg N ha⁻¹ fertilizer in combination with 10 t ha⁻¹ FYM over the control head yield (38.10 t ha⁻¹).

In another field experiments the application of 240 kg N, 45 kg P, 180 kg K and 45 kg S ha⁻¹ performed best in recording plant height, root length, number of loose leaves and heading leaves, leaf length and breadth, thickness and diameter of head and yield. The maximum marketable yield (87.09 t/ha) was recorded in an application of 240 kg N, 45 kg P ha⁻¹ (Brady, 2003). Lesic *et al.*, (2004) reported that cabbage has high requirements for all nutrients, especially nitrogen and for achieving high yields it ranged from 130 to 310 kg N ha⁻¹

Due to the unavailability and high cost of chemical fertilizers, most smallholder farmers in tropical Africa, like Ethiopia, insufficiently use inorganic fertilizers on production of crops. Most smallholder farmers in Ethiopia practice application of inorganic fertilizers below the recommended rates for crop production (Bumb and Baanate, 1996). On the other hand, organic fertilizers are still a primary source of mineral elements, particularly among the resource-poor farmers of developing countries. But the use of organic fertilizers such as farm yard manure for crop production depends largely on the prevailing farming system. Organic manures also are an important source of plant nutrients but contain relatively in small amounts, which are not readily available. On the other hand, inorganic fertilizer contains specific, higher, and readily available plant nutrients. So the combination of organic manures and inorganic fertilizers is likely to be more productive.

In the study area where crop and livestock production are somewhat integrated, farmyard manure could become a major nutrient source for crops and reduce the need for the costly inorganic fertilizers. Moreover, nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect thus supporting better root development, leading to higher crop yields (Bhuiyan, 2010). However, the use of organic fertilizers alone, to sustain cropping has been reported to be inadequate due to unavailability in the required quantities and their relatively low nutrient contents (Palm *et al.*, 1997).

Thus, the combined use of organic and inorganic fertilizer sources can improve soil health and maximize production of cabbage, and as it involves utilization of local resources is assumed to be rational, realistic and economically viable way of supplying of nutrients to crop. MoARD (2011) on crop variety register bulletin indicated to use 235 kg ha⁻¹ N and 110 kg ha⁻¹ P for production of head cabbage. However, access to new and improved agricultural technologies is highly limited in

Gudji zone of Oromia Region most probably due to remoteness from the center and inaccessibility of the area. The potential of horticultural crops especially vegetables is not exploited in this part of the region due to lack of improved varieties, poor management practices, biotic and abiotic stresses high intensity and long duration of rainfall. So far the research institutions in the country have released many varieties of horticultural crops including cabbage. However, these technologies have not reached in full package to farmers in the study area. Thus, lack of improved management practices are the main production constraints of the area.

Therefore, this study was conducted to assess the effect of combined application of nitrogen and farmyard manure on growth, yield and yield components of head cabbage and to identify economically appropriate rates of nitrogen and farmyard manure that maximize yield of head cabbage.

Materials and Methods

Description of the study sites

The experiment site is located in southern Ethiopia in one of the highland and high rainfall areas of the Oromia National Regional State. The site is found in Bore woreda about 8 km west of the town in Songo Bericha Kebele just on the side of the main Addis Ababa to Borena Negelle road via Awasa. It is about 385 km south from Addis Ababa. Geographically, the experimental site is situated at latitude of 6°26'52" N, longitude of 38°56'21" E and at an altitude of 2736 masl. The climatic condition of the area is moist humid and sub humid moisture condition, with relatively longer growing season. The area is found at the annual rainfall ranges from 1400-1800 mm with a bimodal pattern that extended from April to November (Anonymous, 2013). The mean annual minimum and maximum temperature is 10.1 °C and 20 °C, respectively. The type of the soil of the experimental site is red basaltic soil (Nitosols) and Orthic Aerosols. The soil is clay loam in texture and moderately acidic with pH around 6.5 (Yazachew and Kasahun, 2011).

Description of the experimental materials

Thomas F1 variety was used as experimental material. The seed of this variety were collected from the Seed Project Company Limited, Bejo Seed B.V. Crop Grow Crop Production PLC. The choice of this vegetable was due to its adaptability and short vegetative cycle. The

seed of variety is found in the market at large, it is widely cultivated, and consumed in different highland parts of the zone. Urea (46% N), DAP (46% P₂O₅+ 18% N) and TSP (20 % P₂O₅) for control treatments was used as sources of N and P, respectively. Animal dung was collected and composted in a pit for five months to produce farmyard manure. The chemical nutrient content of the farmyard manure was analyzed and summarized as indicated in the appendix table 3.

Treatments and experimental design

The experiment was arranged in factorial combination of four level of farmyard manure (0, 3, 6 and 10 tons ha⁻¹) and five levels of Nitrogen (0, 59, 119, 235 and 294 kg ha⁻¹) while DAP for nitrogen containing and TSP for control treatments will be applied for all plots. The experiment was laid out in randomized complete block design (RCBD) in factorial combination with three replications. The spacing of the plants was 50 cm between rows and 40 cm between plants. The distance between plot and block was 0.8 m and 1.2 m, respectively. Six rows per plot and nine plants per row, totally 54 plants per plot were established in gross plot size of 3m by 3.6m. Therefore the net experimental or harvestable plot size of 2m by 3.6m was used

Soil and farmyard manure sampling and analysis

Soil samples to a depth of 30 cm were collected in a zigzag way from different spots of the experimental field before land preparation and after harvest were taken and composited. After harvest soil sampling was taken in the same manner as taken for the pre planting in a zigzag way from 15 different plots. Then the composite samples were analyzed for physico-chemical properties of the soil mainly for organic carbon, total N, soil pH, available phosphorus, cation exchangeable capacity (CEC), and texture at Melkasa and Holeta Agricultural Research Center soil laboratories for soil and manure, respectively. The soil pH was measured potentiometrically in the supernatant suspension of 1:2.5 soil-water suspensions with standard glass electrode pH meter (Van Reeuwijk, 1992). The Walkley and Black (1934) method was used to determine the organic matter content and the result was obtained by multiplying percent organic carbon by a conversion factor of 1.724. The total nitrogen content of the sampled soil was determined following Kjeldahl digestion, distillation and titration procedure as described by Cottenie (1980). Besides, available phosphorus was determined by Olsen *et al.*, (1954) method. The cation exchange capacity (CEC) was measured using 1M-

neutral ammonium acetate (Jackson, 1967). The soil particle size distribution was determined using the hydrometer technique (Ryan *et al.*, 1965). The manure sample was taken from the well decomposed collected material. The manure was collected from known farmer near to the experimental site and composted the research station site, and air dried, and analyzed at laboratory for pH, total N, available P, available K, CEC and organic carbon content.

The analytical results indicated that the textural class of the soil was sandy clay loam soil profile (Appendix Table 1). Accumulation of different organic materials during previous growing seasons might have resulted in very high pre-plant organic carbon content (3.32%), which might have contributed to the medium level of total N (0.21%), medium level of available phosphorus (5.3%), high level of available potassium (7.41cmol(+) kg⁻¹), high organic matter (5.73%) and medium level of CEC (13.26 cmol(+) kg⁻¹) in the soil. Berhanu (1980) and Tekalign *et al.*(1991) rated 0.12-0.25% total N as medium, >5.17% OM as high and available phosphorus range 5-10 mg kg⁻¹ as medium while available K range 0.6-1.2 cmol(+) kg⁻¹ as high.

The soil pH was also slightly acidic with a value of 6.2 (pH-H₂O). Cation exchange capacity (CEC) is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. Accordingly, CEC of the experimental soil (13.26 cmol kg⁻¹) could be considered as optimum for production of the crop.

Generally, the soil physical and chemical analysis results indicated that the soils of the experimental fields are potentially productive from the perspectives of chemical properties of soils for cabbage growth and had a potential to respond to fertilizer application.

Management of the experiment

The seedlings were grown on the well prepared nursery seedbed and transplanted at 45 days after sowing. Before conducting the research, nursery bed preparation and sowing was done. The nursery was prepared at by removing plant residues and breaking bigger soil particles. At the same seeds of cabbage bought from Bejo Seed B.V. crop production PLC and were raised in the nursery 45 days before transplanting and watered once a day until the seedlings were ready to be transplanted. Only short sturdy, slightly hardened

seedlings of about 10-15 cm tall and with 4-5 true leaves was transplanted. Replanting or refilling was done after ten days for the missed plot. The land was loosened three times with tractor and oxen power. Six to nine months old animal dung was collected and composted in a pit for five months to produce farmyard manure. The composted farmyard manure was applied to the soil one month before planting and incorporated into the soil in order to combine well with soil. Before spreading farmyard manure, the soil was loosened to a depth of 30cm; thereafter the soil was moistened to prevent the farmyard manure from drying. All doses of nitrogen and P were applied once at time of transplanting. Other agronomic practices including weeding, gap filling and cultivation were done uniformly as per required in all plots.

Crop data collection

Phenological data

Days to head initiation: Days to 50% head initiation was recorded when half of the plants in a net plot formed heads.

Days to head maturity: It was recorded from the date of transplanting to when 90% of the heads from the net plot reached maturity. This was determined by the compactness or firmness of the head.

Growth parameters

Plant height: The height of the plant was measured by placing a meter scale from ground level to the tip of the outer longest leaf of an individual plant at the time of 90% days to head maturity. Thus, mean of five selected plants of a single plot was recorded and expressed in centimeter (cm).

Number of expanded leaves per plant: The number of leaves per plant was counted and mean of five plants was recorded before the start of head initiation excluding unfolded and dead leaves.

Yield and yield components

Field stand count: Field stand count was recorded at harvesting from net plot areas.

Shoot mass: Shoot fresh mass was obtained by taking the weight of shoots separately from five representative plants per plot by uprooting and cutting at harvest and finally converted to g per plot.

Height of head: Head height (cm) was obtained from five representative plants per plot and measured by cutting vertically using a ruler at the time of harvesting.

Diameter of head: Five heads were taken randomly. Then sectioning of head was done horizontally with a sharp knife at the middle portion. The diameter of head was measured as the horizontal distance from one side to another side of the selected head and was expressed in centimeter (cm).

Fresh weight of untrimmed head per plant: The fresh weight of heads with unfolded leaves per plant was found from the average weight of selected five plants and expressed in gram (g) when yield data was taken.

Fresh weight of trimmed head per plant: The fresh weight of marketable head per plant was found from the average weight of five plants and was expressed in gram (g) when yield data was taken.

Gross head yield with wrapper: Heads with unfolded leaves of all the plants within a net plot (harvested area 2 m×3.6 m) was recorded and converted to tons per hectare.

Marketable yield per plot: Heads without unfolded leaves of all the plants head within a net plot (harvested area 2 m×3.6 m) was recorded and converted to tons per hectare.

Fresh biomass yield: It was obtained by recording all the above ground plant parts of five sampled plants and expressed in kg per plot and later converted to tons per hectare.

Partial budget analysis

Cost benefit analysis was done to determine the relative economic returns on the applied treatments using the prevailing market prices. The yields were adjusted by 10% downwards due to management level variability between a researcher and a farmer (CIMMYT, 1988). Costs of farm services were taken at Bore market in the southern part of Ethiopia. The economic indicators used were:

Gross benefit: This is the product of the adjusted yield ($t\ ha^{-1}$) and the sale prices. It was calculated by multiplying the yield in $t\ ha^{-1}$ by the market price.

Net benefit: It was calculated by subtracting the total cost of production from the gross benefit.

Marginal analysis: This compares the net benefits with the total variable cost. The total variable cost was determined for each treatment and was compared with the net benefit.

Dominance analysis: Treatments were arranged in terms of increasing variable costs. The corresponding net benefits were also indicated. A treatment is dominant when it has a higher cost but a lower net benefit than any preceding treatment.

Marginal Rate of Returns (MRR): It is the percentage change in benefit over change in total variable cost in moving from a lower cost treatment to a higher one. All the treatments were arranged from the highest to the lowest in terms of profitability. This was achieved by dividing the total variable cost by the net benefit multiplied by 100.

$$\text{MRR (\%)} = \frac{\text{Marginal benefit}}{\text{Marginal Cost}} \times 100$$

Statistical data analysis

The collected data on various parameters of the crop under study were statistically analyzed using SAS statistical package (Gomez and Gomez, 1984). The Least Significant Difference (LSD) test at 5% level of significance was used to separate the means when the ANOVA showed the presence of significant difference.

Results and Discussions

The present experiment was conducted to find out the combination effects of nitrogen and farmyard manure on growth and yield of cabbage. Therefore, the effects of nitrogen and farmyard manure and their interaction effects on growth and yield of cabbage have been presented and discussed in different tables (Tables 1–15) in this chapter.

The analysis of variance of the data of different yield contributing characters and yield has been presented in Appendices. The results of the experiment and possible interpretations have been made under the following headings.

With this the Soil and Farmyard Manure laboratory analysis was presented in table below.

Plant height and number of expanded leaves Plant height

Nitrogen and Farm yard manure fertilization has a very highly significantly ($P < 0.001$) increased most of the growth parameters considered in this study. So plant height was increased highly significantly ($P < 0.001$) with main effect of nitrogen supply and also for the manure application (Appendix Table 6).

All the treatment combinations with N and FYM were recorded significantly different cabbage plant height. There was also a highly significant ($P < 0.001$) interaction effect of the nutrients on the plant height of the crop (Table 2). Thus there were significance differences between the mean plant heights (43.2cm) versus FYM of (10 t ha^{-1}) with each level of N (235 kg ha^{-1}) for plant height. Similarly the treatments received FYM of (10 t ha^{-1}) with each level of N (294 kg ha^{-1}) also shows highest mean plant height (41.61cm). This means treatments receiving highest nutrient of 10 t ha^{-1} versus 235 kg N and 294 Kg N ha^{-1} responds the same. As it was observed from the data the plant height has an increasing trend in plant height growth considered with in increasing combined rate of applied N and FYM. Similar results were noted by Sarker *et al.*, 1996 that significance in plant height of cabbage was observed as the rate of N and FYM increased. Sanderson and Ivany (1999) have also reported that increase in Nitrogen levels up to 150 kg ha^{-1} and phosphorus levels up to 120 kg ha^{-1} increased plant height of head cabbage over its lower levels.

Baloch *et al.*, (2001) experiment on head cabbage result signifies that increased use of Nitrogen and FYM leads to increased plant height.

This result is in agreement with that of Sarker *et al.*, (2003) who observed that good plant height obtained in response to increased N supply improved significantly due to the presence of FYM.

The increment in plant height due to FYM application may be due to the fact that organic fertilizer improves the soil structure and aggregation; this change can improve availability of nutrients as well as encourage the plant to have good root development by improving the aeration in the soil, which leads to a higher plant growth. In our study there was an increasing trend in the plant height parameter with the increasing in the rate of applied both N and FYM.

Number of expanded leaves

Different level of Nitrogen and Farmyard manure fertilization alone has highly significantly differently ($P < 0.001$) increased number expanded leaves in the study. So plant leaves was increased highly significantly ($P < 0.001$) with main effect of nitrogen and farmyard manure supply also for the interaction effect of both N and FYM application (Appendix Table 6).

In this parameter all the treatment combinations with N and FYM were recorded significantly different cabbage number of expanded leaves (Table 3). The highest Number expanded leaves (16.66) of cabbage plants tended to increase by increasing combined dose of organic manure and inorganic N fertilizers. Also, number of leaves per plant showed a little increase with increased organic manure dose (10 t ha^{-1}) and Nitrogen fertilizer (294 kg ha^{-1}). Each increase in Nitrogen and FYM fertilizer dose tended to increase number of leaves per plant compared with control. Generally, plots receiving a combined nutrient of N and FYM fertilizers produced higher ($P < 0.001$) number of leaves. Thus, through the increase in photosynthetic activity of leaves, it further encourages vegetative growth of plants as reported by (Archer. 1988; Marschner.1995). These results are in accordance with Magnusson (2002) on chinensis cabbage (*Brassica chinensis*) that he observed highest numbers of leaves of Chinese cabbage were obtained by application of 10 ton ha^{-1} organic manure with combination of 200 kg ha^{-1} nitrogen fertilizer.

Our ANOVA result revealed that the number of cabbage leaves increased as organic fertilizer rates increased (Table 3). Khadir *et al.*, (2002) also observed suggested that combined application of different inorganic and organic fertilizers increased both vegetative and leaf number in cabbage growth. They noticed that application of 20 t ha^{-1} FYM with combined rate of 250 kg N ha^{-1} produces more expanded leaves instead of compact head. In cabbage, leaves play an important role for photosynthesis. For this reason, the number of leaves per plant was an important yield-contributing factor. In this experiment, generally it was found that different level of nitrogen and FYM practices had showed significant ($P < 0.001$) effect on plant height and number of leaves per plant.

The highest rate of nutrients application resulted in plants with more vegetative and leaf growth as compared to the lower rates which could be attributed to the low initial content of N and FYM. The number of leaves had a trend of increased gradually from control and reached

its peak at 294 kg N ha^{-1} with 10 t ha^{-1} manure. Gulser (2005) Also showed that there was a significant difference in the number of leaves among different level of combined application of 200 kg N ha^{-1} and 15 t ha^{-1} organic manure that the highest leaf number was obtained with. Vimala *et al.*, (2006) also reported that increments in the N rate of the fertilizers with FYM increased the number of leaves in spinach. Therefore combined application of organic and inorganic fertilizer stimulated vegetative growth by increasing the number of leaves.

Days to 50% head initiation and 90% maturity of cabbage

Days to 50% head initiation

The main effect of N was highly significant ($P < 0.001$) on this parameter to reach head initiation. FYM had also highly significantly ($P < 0.001$) different main effect on head initiation, and also the interaction effect of both N and FYM show highly significant different ($P < 0.001$) on this parameter (Appendix Table 6).

Days to start of head formation from transplanting of Chinese cabbage showed significant differences ($P < 0.001$) with different levels of nitrogen with combined FYM application in the present trial. All the combined level of nitrogen fertilizer with FYM showed a gradual retarding tendency of days to starting head formation of Chinese cabbage as the dose decreased (Table 4). The shortest head initiation duration (63.33) was recorded in 294 kg N ha^{-1} and $10 \text{ ton manure ha}^{-1}$, where the longest (81.66) was recorded in control. The results indicated that the treatments received high doses of nutrients resulted in delayed of different reproductive growth phases whereas the onset of different reproductive phases were drastically hastening in case of plants received low rate of nutrients or no nutrients. This result agreed with Chaubey *et al.*, (2006) who found significantly shorter time (57.45) of cabbage for head initiation under the treatment receiving nitrogen and farmyard manure fertilizer ahead of control treatment.

The ANOVA result revealed that days to head initiation inversely correlated with the nutrient rates. That means as the combined rate increased the days 50% head formation negatively decreased. In another interpretation the more we use the nutrients the early the crop head to form. Haque *et al.*, (2006) also observed that higher fertility level favored the head initiation and maturity of head cabbage.

Days to 90% maturity of cabbage

The main effect of N was highly significant ($P < 0.001$) on days to maturity. FYM had also highly significantly ($P < 0.001$) different main effect on days to maturity, and also the interaction effect of both N and FYM show highly significant different ($P < 0.001$) on this parameter (Appendix Table 6).

The interaction effect of Nitrogen and FYM rate showed significant difference ($P < 0.001$) in days to maturity (Table 5). Head cabbage planted in combination of Nitrogen (294 kg ha^{-1}) and Farmyard manure (10 ton ha^{-1}) matured earlier (112) compared to other treatments. Treatments treated with highest combination rates took shorter period to mature as compared to control treatment. This is because of the effect of both high rate of N and FYM in delaying the vegetative phase and hastening head formation and maturity of different reproductive growth phases. Generally cabbage that received the highest N and FYM rates reached maturity earlier than those received no or low N rates. This result is in agreement with that Wilcox and Hoff (1970), who reported that combined use of inorganic and organic nutrients was associated with delays in plant maturity. This is because of the essential nutrients accelerated the plant growth. In contrast to N, however it hastened maturity of the plants. Thus, the cabbage plant treated with highest nutrients supply had their time to physiologically mature earlier by 27 days compared to the untreated treatments. Rosen and Eliason (2005) demonstrated the importance of N for early crop growth and crop to mature. Sisay *et al.*, (2008) reported that the shortest duration of carrot plants to reach maturity was recorded for the highest level of N (309 kg ha^{-1}) and P (68 kg ha^{-1}) who reported that excessive N fertilizer hastened maturity of crop plants while low levels of N delayed the maturity.

Field stand count

Analysis of data for both nitrogen and farmyard manure revealed non-significant ($P > 0.05$) main effect on field stand count. Also the interaction effect of both N and FYM had non-significant ($P > 0.05$) on this parameter (Appendix Table 7).

Head height and head diameter

Head height

Analysis of data for both nitrogen and farmyard manure revealed highly significant ($P < 0.001$) main effect on head height (Appendix Table 6).

Also the interaction effect of both N and FYM had also significant different effect ($P < 0.001$) on this parameter (Table 6). Nitrogen and FYM fertilization had significant ($P < 0.001$) interaction effect on head height of the crop. The combined effect of nitrogen and FYM was important for most of the characters of head cabbage (Table 6). Combined application of 235 kg N and 6 t FYM ha^{-1} recorded highest head height (18.14 cm). The least head height (13.86 cm) was recorded for the treatment received highest ($294 \text{ kg ha}^{-1} + 10 \text{ t ha}^{-1}$) amount of applied nutrients. The head height obtained by fertilizing $235 \text{ kg N} + 6 \text{ t FYM ha}^{-1}$ was 76.4% higher than those of the over fertilized treatment and also 78.9% higher than the control treatment. The height trend is increasing with an increase in the combined rate of N and FYM to the certain level but, decreases after $235 \text{ kg N} + 6 \text{ t FYM ha}^{-1}$ rate. This result is in conformity with the observation of Ciszinszky and Schester (2001) that combined application of 200 kg N ha^{-1} with 20 t ha^{-1} FYM resulted in the highest head height of cabbage (17.67 cm).

Thus, the results of the experiment indicated a significant response of N and FYM with respect to head height. Krezel and Koota (2004) also conducted a research in Florida, to investigate the effect of nitrogen on yield of cabbage and found that nitrogen rate of 227 kg ha^{-1} with 30 t ha^{-1} FYM increased head height (19.23 cm) of cabbage. Nutrient levels noticeably influenced the diameter and height of head cabbage. Balanced use of nitrogen and farmyard manure significantly increased the head height and reduced the percentage of deformed head as compared to lower and extremely high dose of nitrogen and farmyard manure. The results are also similar with the Journal of Crop and Weed, 5(2): 75-77 (2009) findings of Felozynski *et al.*, (2004).

Diameter of cabbage

Application of FYM also showed significantly different ($P < 0.001$) main effect on Head diameter of head cabbage plant as like the height of the head (Appendix Table 6). Normally the increasing head height parallels with the head diameter expressed by positive and highly significant correlation value. Also the interaction effect of both N and FYM had also significant different effect ($P < 0.001$) on this parameter (Table 7).

The interaction effect between Nitrogen and FYM combination was also highly significant ($P < 0.001$) for head diameter under our study (Table 7). It was observed that N and FYM application at different levels recorded a remarkable change in diameter of head cabbage. Head

diameter was increased with the increase nutrient doses up to 235 kg N and 6 ton ha⁻¹ FYM. Similarly head diameter was increased with increase doses of nutrients till 235 kg N and 6t ha⁻¹ FYM in combination. Combined application of 235 kg nitrogen and 6 ton ha⁻¹ recorded maximum number of head diameter (17.03cm). The lowest head diameter (12.49cm and 12.52cm) was recorded for the treatment received no nutrients and highest (294 kg ha⁻¹ + 10t ha⁻¹) amount of applied nutrients respectively. In this result our ANOVA summary revealed that both the control and 294 kg + 10 t FYM ha⁻¹ treatment did not show significant differences. The interaction effect between nitrogen and farmyard manure combination was significant for most of the characters under our study. This result was corroborated with the findings of Peck (1998) in cabbage that the diameter of the head increased as the rate of application increased than the least applied treatments. Arisha *et al.*, (2003) also reported that significantly higher diameter of head in cabbage by the application of 120-90-80 kg NPK ha⁻¹ respectively, with a combination of 20 t FYM ha⁻¹. There was a strong positive correlation between diameter of head and marketable head per plant.

Regardless of organic manure dosages, each increase in inorganic fertilizers dose caused a gradually increased in diameter of heads at 0 and 119 kg N ha⁻¹. Application of 235 kg ha⁻¹ Nitrogen fertilizer with different organic manure doses produced significantly larger heads diameter compared with control and 294 kg ha⁻¹ Nitrogen fertilizer. Positive effects of Nitrogen fertilizers and organic nutrients on head diameter of cabbage may be due to the better availability of soil nutrients that produced healthy plants with large vegetative growth, which reflected in the height and head diameter and improvement of soil chemical and physical properties by using Farmyard manure Wong *et al.*, (1999).

All data indicated that, it is worthy to notice the positive effect of combined application of organic and inorganic fertilizer. It is obvious that farmyard manure had a promising effect on all growth parameters including height and head diameter. These results are in agreement with those obtained by (Roe and Cornforth, 2000) that showed combined application of organic and inorganic fertilizer increase head height and head diameter growth of cabbage plants at certain level but decreases the head quality. Subhan (2008) carried out an experiment on cabbage and observed that application of 15t ha⁻¹ FYM with 200kg N ha⁻¹ increased head diameter (15.87cm) after planting.

Shoot mass

Analysis of data for both main effect of nitrogen and farmyard manure revealed non-significant ($P > 0.05$) main effect on shoot mass and the interaction effect of both N and FYM had also non-significant ($P > 0.05$) on this parameter (Appendix Table 7).

Untrimmed and trimmed head weight

Untrimmed head weight

The untrimmed weight of head was significantly ($P < 0.001$) influenced by the application of different levels of nitrogen and farmyard manure nutrients and interaction effect of both N and FYM on head growth character of Chinese cabbage (Appendix Table 7).

Nitrogen and FYM had a significance ($P < 0.001$) interaction effect on mean head weight (Table 8). A summary of the analysis of variance determining the effect of different Nitrogen fertilizers and Farmyard manure rates on untrimmed and trimmed head weight of cabbage indicates that head weight responded differently. Application of the highest dose of Nitrogen fertilizer (235 kg ha⁻¹) with the dose of organic manure (6 t ha⁻¹) produced a comfortable highest untrimmed head weight (2296.67g) of cabbage which remained far with the untreated treatment. In this parameter the least mean untrimmed head weight (883.33g) was recorded for the control and treatments received 294kg N+ 10t FYM ha⁻¹. Meaning, application of the highest dose of organic manure (10 ton ha⁻¹) in combination with Nitrogen (294kg N ha⁻¹) caused a reduction in head weight compared with application of 6 ton ha⁻¹ organic manure in combination with 235kg nitrogen fertilizer ha⁻¹ (Table 8). The result indicates that unbalanced nutrient application due to toxicity or in efficiency leads to decrease in the head mass. In general our result revealed that treatment combinations with Nitrogen and Farmyard manure fertilizers were recorded significantly different higher cabbage head weight over the control. Gupta (1987) reported maximum untrimmed head weight (2220g) of cabbage is obtained at 150 kg ha⁻¹ N and 20t ha⁻¹ FYM. In his experiment the maximum yields from 150 kg ha⁻¹ N and 20 t ha⁻¹ FYM were attributed mainly to increase in head mass. Preece and Read (2005) also reported increases in untrimmed head mass (1537) yielded by the application of 200 kg ha⁻¹ N in combination of 15 t ha⁻¹ FYM beyond which there was a reduction in yield and head weight.

Trimmed head weight

Application of nitrogen and farmyard manure showed significantly different ($P < 0.001$) main effect on trimmed head weight of head cabbage. Interaction effect of N and FYM also showed significantly different ($P < 0.001$) on trimmed head weight of head cabbage plant as like the untrimmed head weight of the head cabbage (Appendix Table 7).

Similarly like untrimmed head weight our ANOVA result the addition of Nitrogen and FYM in combination had a significance ($P < 0.001$) interaction effect on mean trimmed head weight (Table 9). A summary of the analysis of variance determining the effect of different Nitrogen fertilizers and Farmyard manure rates on trimmed head weight of cabbage indicates that head weight responded differently. Application of the highest dose of Nitrogen fertilizer (235 kg ha^{-1}) with the highest dose of organic manure (6 t ha^{-1}) recorded a comfortable highest trimmed head weight (1766.67 g) of cabbage which remained far with the control and over fertilized treatment. In this parameter the least mean trimmed head weight (260 g and 313.33 g) was recorded for the treatments received $294 \text{ kg N} + 10 \text{ t FYM ha}^{-1}$ and control treatment respectively. Similarly as the untrimmed head weight, application of the highest dose of organic manure (10 ton ha^{-1}) in combination with highest Nitrogen (294 kg N ha^{-1}) caused a reduction in head weight compared with application of $6 \text{ t FYM ha}^{-1} + 235 \text{ kg N ha}^{-1}$ (Table 9.). In general our result revealed that treatment combinations with Nitrogen and Farmyard manure fertilizers were recorded significantly higher cabbage net head weight over the control and over fertilized treatment. This result is in line with the results of Rincon *et al.*, (1998) who found that increased N and FYM increase the weight of head cabbage. Similarly also observed that application of $200 \text{ kg N} + 15 \text{ t FYM ha}^{-1}$ resulted significantly high average trimmed weight of head cabbage as compared to the average weight of head from the control.

Nitrogen fertilizers above 235 kg N alone, or in combination of organic fertilizers, did not increased significant marketable head weights. This variation was due to the availability of nutrients especially nitrogen and potassium and could be due to the improvement of soil water holding capacity as mentioned by Roe and Cornforth (2000). The reason suggested for such a response was that nitrogen and FYM which is a source of organic matter significantly increased growth parameters, which in return synthesized more plant

metabolites thereby increasing yield. That means as the rate of nitrogen and FYM increases to certain level the mass of the head increases.

The studies carried out by Tei *et al.*, (2000) on head cabbage showed that increasing FYM fertilizer level to 15 t ha^{-1} and Nitrogen fertilizer to 250 kg ha^{-1} increased its net head mass value. A research conducted by White and Forbes (2007) on head cabbage applied manure fertilizer at different levels ($0, 5, 10$ and 20 t FYM ha^{-1}) and Nitrogen fertilizer levels ($50, 100, 150, 200$) for two cabbage cultivars and estimated manure fertilizer rate to obtain maximum marketable head weight (1780 g) at about 10 t FYM ha^{-1} with 150 kg N ha^{-1} for both cultivars. Furthermore, organic manure activates many species of living organisms, which release phytohormones and may stimulate the plant growth and absorption of nutrients. Such organisms need nitrogen for multiplication. This is the reason that the use of organic manure with inorganic fertilizer showed a beneficial effect on both growth and yield.

Yield with wrapper

The analysis of variance revealed that the main effects of nitrogen and farmyard manure had highly significant different ($P < 0.001$) on main effects and interaction response of yield with wrapper (Appendix Table 7).

A summary of the analysis of variance determining the interaction effect of different Nitrogen fertilizer levels and Farmyard manure rates on yield with wrapper of cabbage indicates that significantly different ($P < 0.001$) effect (Table 10.). Application rate of Nitrogen fertilizer (235 kg ha^{-1}) with the combination dose of FYM (6 t ha^{-1}) produced a comfortable maximum (107.47 t ha^{-1}) yield with wrapper head cabbage. However, application of the highest (10 t ha^{-1}) dose of FYM in combination with Nitrogen (294 kg N ha^{-1}) caused a reduction in yield (100.44 t ha^{-1}) compared with application rate of 6 t ha^{-1} organic manure and $235 \text{ kg nitrogen ha}^{-1}$. All the treatment combinations with Nitrogen and Farmyard manure fertilizers were recorded significantly higher yield with wrapper over the control. Our ANOVA result also revealed that the addition of Nitrogen fertilizers above 235 kg N ha^{-1} alone, or in combination of FYM did not increased significant yields. The yield was reduced due to the application of nutrients above 235 kg N ha^{-1} alone and in combination with 6 t FYM ha^{-1} . In the study the least yield (34.82 t ha^{-1}) was recorded for the control treatment.

There was a significant effect of different doses of nitrogen and FYM on yield with wrapper of cabbage. This might be due to the fact that nitrogen supplied readily and the supplied manure also releases available plant nutrients for vigorous growths slowly. Yield with wrapper was reduced due to the application of nutrients above 235 kg N ha⁻¹ and 6 t FYM ha⁻¹ that do not allow the plant to grow effectively. Gupta (1987) reported that the maximum head with wrapper yield was recorded in treatment receiving 120 kg N, 90 kg P and 15 t FYM ha⁻¹ in cabbage. The significant increase in yield with wrapper in response to the increased nitrogen and organic fertilizer levels might be attributed to the positive role of balanced nutrients in the physiology of the plant in cell elongation and enhancing above ground vegetative growth, photosynthesis, and ultimate partitioning of photosynthate to the heads development. Our result is in line with that of Roe and Cornforth (2000) who reported that higher dose (200 kg N ha⁻¹) of nitrogen and 25 t ha⁻¹ FYM produced higher wrapper head yield (78.56 t ha⁻¹) than lower doses of the nutrient. Kumar *et al.*, (2002) also reported that the maximum wrapper head yield (81 t ha⁻¹) was recorded in treatment receiving 250 kg N ha⁻¹ and 20 t ha⁻¹ FYM in cabbage. Moreover the application of FYM and Nitrogen significantly increased all yield and yield related components. This ability of combined use of FYM and Nitrogen to significantly influence this character may probably be due to the fact that combined use supplies nitrogen, phosphorus and micro nutrients to the crop. More so, FYM has high organic carbon content and other macro and micro nutrients such as N, P, K, Ca, Mg and Fe which are essential for good crop growth and nitrogen has a tendency to supply readily available nutrient for the crop. These results are in agreement with those obtained by Din *et al.*, (2007). Stamatiadis *et al.*, (2009) result revealed that highest cabbage head yield (62.3 t ha⁻¹) produced by application of FYM at rate of 10 t ha⁻¹ with 250 kg N ha⁻¹ respectively.

Yield without wrapper

Similar to wrapper yield, the yields of cabbage without wrapper were positively affected by both the Nitrogen and FYM (Appendix Table 7). All treatments received nitrogen had significantly ($P < 0.001$) different main and interaction effect on yield without wrapper. The ANOVA result revealed that highest head yield without wrapper per hectare of 72.36 t ha⁻¹ were observed in the 6 t ha⁻¹ Farmyard manure and 235 kg ha⁻¹ fertilizer combination and the least yield of 19.15 t ha⁻¹ were recorded in the untreated control treatment (Table 11).

The highest combination of 10 t ha⁻¹ farmyard manure and 294 kg ha⁻¹ nitrogen gave a yield advantage of 26.83% over the control. The interaction thus showed response to FYM was more at higher rates of N application. The farmyard manure applied at 6 t ha⁻¹ combined with 235 kg ha⁻¹ fertilizer was just enough to satisfy the yield requirements of cabbage plant in this study. This was evident in the significant yield experienced in the other treatments. This result is in agreement with Preece and Read (2005) that work their research on head cabbage reported, increases in yield up to 200 kg N ha⁻¹ and 20 t FYM ha⁻¹, beyond which there was a reduction in yield. For the current experiment higher yields at higher nitrogen and FYM doses could be attributed to great head height, diameter and yield obtained at nitrogen doses (235 kg ha⁻¹) and FYM doses (6 t ha⁻¹). This result is corroborated by Olaniyi and Ojetayo (2011) who reported that marketable head yield was increased in response to increased rate of nitrogen fertilizer 150 kg ha⁻¹ after which it reduced.

The yield from the experiment was in agreement with the report of Murwira and Kirchman (2007) who found that increased yield (65.43 t ha⁻¹) of cabbage through the combination of farmyard manure (10 t ha⁻¹) and Nitrogen (200 kg ha⁻¹) fertilizer and the findings of Sarker *et al.*, (2003) who reported that the best way to increase cabbage yield was by the combination of organic wastes and nitrogen fertilizer. Aditya (2003) reported that highest, (60 t ha⁻¹) yield of cabbage was obtained by the application of 375 kg N ha⁻¹ along with FYM at the rate of 10 t ha⁻¹. White and Forbes (2007) also worked with cabbage in USA to find out the effect of nitrogen and FYM on the growth and yield of cabbage. They concluded that cabbage yield responded positive to N and FYM combination application up to the level of 308 kg ha⁻¹ and 15 t FYM ha⁻¹. More than this dose resulted reduced head yield proportionately.

The application of N and FYM significantly increased all yield up to certain level, the result is obtained reasonably because of combined utilization significantly influence yield and yield related characters at all levels due to the fact that FYM supplies both macro and micro elements and also inorganic nitrogen have an ability of easily useable by the plant. Similarly the plant food produced by organic manures is as good as that supplied by nitrogen fertilizers. But there is an important difference in that manure is given in large quantity when compared with nitrogen fertilizers and the organic manure gets decomposed very slowly and supply the plant with food in small doses while the nitrogen supply the necessary

requirements all at once in a soluble form. An experiment carried out by Samant *et al.*, (2003) to investigate the balanced N fertilizer and FYM for cabbage using application rate of (40, 60, 80, 100, 140,160, 180 and 200 kg N ha⁻¹) and (5, 10, 15,20,25,30 and 35 t ha⁻¹) respectively, on the marketable head yield of cabbage showed that yield increased to 49.83 t ha⁻¹ with increasing rates of N to 180 kg ha⁻¹ and 25t FYM ha⁻¹. Yield decreased with the further increase in N rates and FYM rates. Generally there was an increasing trend in the yield without wrapper parameter with the increasing in the rate of combined application of N (0, 59,119 and 235 kg ha⁻¹) with FYM (0, 3 and 6 t ha⁻¹).

Organic manures are the main source of soil organic matter, which has a fundamental effect on physical and physiochemical properties of soil. Organic manures also

are an important source of plant nutrients but contain relatively in small amounts, which are not readily available. On the other hand, inorganic fertilizer contains specific, higher, and readily available plant nutrients. So the combination of organic manures and inorganic fertilizers is likely to be more productive. A number of researches have been conducted to investigate the combined effect of organic manures and inorganic fertilizers. According to our result cabbage marketable head yield per hectare was significantly influenced by the application of farmyard manure, Nitrogen and their interaction. Both Nitrogen and organic fertilizer farmyard manure application had a pronounced effect on the yield and yield contributing characters of cabbage in the conducted experiment.

Table.1 Description of the variety (Thomas F1) used for the experiment

Description	Agronomic and morphological Characteristics
Altitude (meters above sea level)	1500-2200
Rainfall amount (mm)	800-1200
Seeding rate (kg/ha)	0.55
Planting season	Year round
Spacing	50 cm between rows and 40 cm between plants
Days to maturity (days)	80 days from transplanting
Head color	Deep green
Plant height (cm)	40-50
Head shape	Round compact
Growth Habit	Erect with blue wrapper leaves
Average head weight (g)	2000
Yield (kg/ha)	700
Year of Release	2011

Source: MoA (2011) Crop Variety Register Bulletin

Table.2 Background of chemical and physical properties of experimental site soil before planting

Soil characters	Values
pH	6.2
Total nitrogen (%)	0.21
Organic carbon (%)	3.32
Available P (mg kg ⁻¹)	5.3
CEC (cmol(+) kg ⁻¹)	13.26
Available K (me/100g soil)	7.41
Organic matter (%)	5.73
Mg (cmol (+) kg ⁻¹)	6.12
Soil texture:	
Sand	52
Silt	20
Clay	28
Class	Sand clay loam

Table.3 Soil physical properties at experimental site after FYM and N decomposition and harvest

Soil characters	Values
pH	6.31
Total nitrogen (%)	0.36
Organic carbon (%)	3.55
Available P (ppm)	5.42
CEC (cmol(+)/kg)	12.23
Available K (cmol(+)/kg)	7.53
Organic matter (%)	6.12
Soil texture:	
Sand (%)	49
Silt (%)	23
Clay (%)	28
Class	Sandy clay loam

Table.4 Chemical properties of farmyard manure used in the experiment

FYM characters	Values
pH	6.5
Total nitrogen (%)	0.356
Organic carbon (%)	31.13 g
Available P (ppm)	38.85
CEC (cmol(+) kg ⁻¹)	26.11
Available K (cmol(+) kg ⁻¹)	2.53

Table.5 Interaction Effect of N and M on Plant Height of Head Cabbage (Cm Plant⁻¹)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	26.64 ^f	27.38 ^f	31.93 ^e	32.47 ^e	34.12 ^{cde}
3	26.83 ^f	33.13 ^{de}	31.83 ^e	33.81 ^{cde}	34.93 ^{cd}
6	27.64 ^f	33.22 ^{de}	34.01 ^{cde}	37.73 ^b	37.98 ^b
10	27.7 ^f	32.44 ^e	35.72 ^{bc}	43.20 ^a	41.61 ^a
LSD(0.05) N*M= 2.36; CV(%)=4.32					

Table.6 Interaction effect of N and M on number of expanded leaves of head cabbage (leaves/plant)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	10.33 ^h	10.66 ^{gh}	13.33 ^{cde}	12.33 ^{def}	12.00 ^{efg}
3	10.66 ^{gh}	12.66 ^{def}	13.66 ^{cd}	13.66 ^{cd}	12.66 ^{def}
6	11.33 ^{fgh}	13.66 ^{cd}	13.66 ^{cd}	14.66 ^{bc}	14.66 ^{bc}
10	12.66 ^{def}	13.33 ^{cde}	14.66 ^{cb}	15.66 ^{ab}	16.66 ^a
LSD (0.05) N*M=1.39; CV (%) =6.44					

Table.7 Interaction effect of N and M on days of 50% head initiation of head cabbage (days)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	81.66 ^a	77.66 ^b	72.66 ^c	68.66 ^d	64.33 ^e
3	78.33 ^b	78.00 ^b	72.00 ^c	67.66 ^d	64.00 ^e
6	77.33 ^b	73.00 ^c	63.66 ^e	63.33 ^e	63.33 ^e
10	73.33 ^c	72.00 ^c	73.33 ^c	67.66 ^d	63.33 ^e
LSD (0.05) =1.43; CV (%) =1.22					

Table.8 Interaction effect of N and M on days of 50% maturity of head cabbage (Days)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	140.66 ^a	135 ^b	127.66 ^{cde}	122.00 ^{fgh}	113.66 ⁱ
3	133.33 ^b	128.00 ^{cd}	127.66 ^{cde}	118.66 ^h	113 ⁱ
6	129 ^c	127.66 ^{cde}	119.66 ^h	119.33 ^h	112.00 ⁱ
10	123.66 ^{efg}	124 ^{def}	118.66 ^h	112.66 ⁱ	113.00 ⁱ
LSD (0.05) =4.09 CV (%) =2.01					

Table.9 Interaction effect of N and M on Head Height of head cabbage (cm/head)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	14.32 ^{ghij}	14.10 ^{ij}	14.24 ^{hij}	14.53 ^{efghi}	14.64 ^{defghi}
3	14.41 ^{fghij}	14.68 ^{defghij}	15.23 ^{cd}	16.36 ^b	15.53 ^c
6	14.99 ^{cdef}	14.92 ^{defg}	16.26 ^b	18.14 ^a	14.23 ^{hij}
10	14.82 ^{defgh}	15.06 ^{cde}	16.14 ^b	16.66 ^b	13.86 ^j
LSD (0.05) = 0.59; CV (%) =2.4					

Table.10 Interaction effect of N and M on Head Diameter of head cabbage (cm/head)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	12.49 ^k	13.80 ^{ijk}	13.12 ^{ghijk}	13.52 ^{ghij}	14.40 ^{def}
3	12.64 ^{jk}	13.45 ^{ghij}	13.84 ^{efg}	13.55 ^{fghi}	15.41 ^{bc}
6	13.46 ^{ghij}	13.49 ^{ghij}	14.70 ^{cde}	17.03 ^a	12.90 ^{hijk}
10	13.72 ^{fgh}	13.82 ^{fg}	14.98 ^{cbd}	15.66 ^{bcd}	12.52 ^k
LSD (0.05) = 0.88 CV (%) = 3.83					

Table.11 Interaction Effect of N and M on Head Weight of Untrimmed of Head Cabbage (g/head)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	883.33 ^j	1323.33 ^h	1483.33 ^{efg}	1660 ^d	1486.67 ^{efg}
3	1163.33 ^j	1480 ^{efg}	1766.67 ^c	1576.67 ^{de}	1616.67 ^d
6	1320 ^j	1440 ^{fg}	1610 ^d	2296.67 ^a	1620 ^d
10	1386.67 ^{gh}	1650 ^d	1506.67 ^{ef}	1946.67 ^b	883.33 ^j
LSD (0.05) = 102.61; CV (%) = 4.13					

Table.12 Interaction Effect of N and M on Head Weight of Trimmed of Head Cabbage (g/head)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	313.33 ^k	793.33 ^{ghi}	933.33 ^{ef}	1140 ^{cd}	613.67 ^j
3	633.33 ^j	956.67 ^{ef}	1250 ^c	1016.67 ^{de}	700 ^{ij}
6	790 ^{hi}	933.33 ^{efg}	1056.67 ^{de}	1766.67 ^a	616.67 ^j
10	873.33 ^{fgh}	1120 ^{cd}	1000 ^{def}	1456.67 ^b	260 ^k
LSD (0.05) = 142.59; CV (%) = 9.47					

Table.13 Interaction Effect of N and M on yield with rapper of head cabbage (ton/ha)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	34.82 ^p	58.76 ^{lm}	72.00 ^{shi}	76.69 ^{fg}	78.94 ^{fg}
3	42.73 ^o	62.24 ^{kl}	80.70 ^{ef}	87.89 ^c	83.3 ^{de}
6	50.2 ⁿ	64.86 ^{jk}	88.92 ^c	107.47 ^a	85.65 ^{cd}
10	56.28 ^m	68.03 ^{ij}	96.68 ^b	100.44 ^b	75.3 ^{gh}
LSD (0.05) = 4.25; CV (%) = 3.49					

Table.14 Interaction effect of N and M on yield with out rapper of head cabbage (t/ha)

Manure (ton ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	19.15 ⁿ	39.22 ^{jk}	48.46 ^{gh}	53.92 ^{ef}	53.58 ^{efg}
3	24.85 ^m	41.85 ^{ijk}	56.62 ^{cde}	59.65 ^{cd}	55.52 ^{de}
6	31.53 ^l	43.17 ^{hij}	61.58 ^{bc}	71.36 ^a	57.08 ^{cde}
10	36.38 ^{kl}	45.23 ^{hi}	61.88 ^{bc}	66.74 ^{ab}	48.30 ^{gh}
LSD (0.05) = 5.48 CV (%) = 6.8					

Table.15 Interaction Effect of N and M on Biomass yield of Head Cabbage (ton ha⁻¹)

Manure (t ha ⁻¹)	Nitrogen (kg ha ⁻¹)				
	0	59	119	235	294
0	34..2 ^p	58.76 ^{lm}	72.0 ^h	76.69 ^f	78.94 ^{fg}
3	42.7 ^o	62.24 ^{kl}	80.7 ^e	87.89 ^c	83.33 ^{de}
6	50.2 ⁿ	64.86 ^{jk}	88.9 ^c	107.4 ^a	85.65 ^{cd}
10	56.3 ^m	68.03 ^{ij}	96.7 ^b	100.4 ^b	75.29 ^g
LSD (0.05) = 42.48; CV (%) = 3.5					

Biomass yield

Both N and FYM had highly significantly ($P < 0.001$) different main effects on the biomass yield of the head cabbage (Appendix Table 7). What is more, there was also a highly significant ($p < 0.001$) interaction effect of the two nutrients on this parameter of the plant.

As the summary of ANOVA revealed (Table 12) both nitrogen and farmyard manure have significantly interact at $P < 0.001$. The results showed that all nitrogen and farmyard manure treatments significantly increased the biomass yield of cabbage crop on each treatment. The maximum biomass yield of 107.47 t ha⁻¹ was obtained in treatment receiving N from UREA of 235 kg ha⁻¹ and FYM of 6 t ha⁻¹ combination and followed by those receiving 235 kg N with an addition of 10 t FYM ha⁻¹ yielding 100.44 t ha⁻¹ biomass yield. But the biomass yield was minimum (34.21 ha⁻¹) in the control treatment. Consistent biomass yield increment was observed at control, 59 and 119 kg N ha⁻¹ with all rates of Farmyard manure. Vachani and Patel (1991) also reported that increase in biomass yield with increase in N up to 200kg ha⁻¹ significantly augmented leafy yield of head cabbage.

These findings are also in agreement with Haque (2000) who reported significant increases in cabbage head yields

with addition of FYM to nitrogen fertilizers as compared to control treatment. The interaction of different rates of recommended dose of nitrogen fertilizers with various rates of farmyard manures had a significant effect on biological yield (Table 12). Generally it was observed that treatments that received both FYM and inorganic nitrogen fertilizer produced plants with more biomass yield as compared to plants in unfertilized plot. Chowdahury *et al.*, (2002) also reported that plants treated with both organic and manure was significantly higher in biomass. It is also interesting to note that the least above ground biomass was recorded with absolute control treatment.

Generally the amount the trend of biomass increased slightly as N and FYM level increased from 0 to 235 kg ha⁻¹ and 0 to 6t ha⁻¹ respectively (Table 13) in the study area. These results suggest that N and FYM have a potential of increasing biomass yield which will then be incorporated into the soil for the benefit of the subsequent and readily available crop. However higher level of N (294 kg) and FYM (10t) is not desirable as it causes biomass yield decline. The increase in the uptake of nutrients by cabbage head with application of N along with FYM is obvious as it is considered as a storehouse of plant nutrients, which provide optimum nutrients for crop and yields highest biomass. The finding of Kaur *et*

al., (2005) concluded in his research work that excessive use of inorganic and organic manure causes reduction in biomass of cabbage crop.

Correlation analysis

Correlation coefficient values (r) computed to display the relationships between and within agronomic parameters of head yield of cabbage are shown in Appendix Table 1. The correlation values explain the apparent association of the nutrient parameters and yield components with each other and clearly indicated the magnitude and direction of the association and relationships. Among the several yield components, days to head initiation, maturity and days to harvesting were negatively correlated with the nitrogen and farmyard manure concentration and uptake of the plant. This means as the rate uptake of the plant increases the days to head initiation, maturity and harvesting inversely decreased.

In another case yield parameters of yield with wrapper, yield without wrapper, biological yield, plant height and number of expanded leaves were highly positively correlated with nitrogen and farmyard manure concentration and uptake of the plant. Thus, the result implied that increased N and FYM uptake and its concentration in the plant maximize the indicated parameters. This agreed with the physiological aspect of the nutrient imposed on plant growth and development (Mbatha. 2008). Similarly head height, head diameter, head weight untrimmed, trimmed and harvest index responded positively to the concentration of nitrogen and farmyard manure but not significantly. This implies that increase in N and FYM increases for the mentioned parameter, but not significantly correlated.

The correlation analysis between total net yield ($t\ ha^{-1}$) and yield and growth characters indicated that, net yield was positively correlated with mean plant height ($r=0.71^{**}$), number of leaves ($r=0.65^{**}$), head height ($r=0.65^{**}$), head diameter ($r=0.68^{**}$), head weight untrimmed (0.76^{**}), head weight trimmed (0.62^{**}), yield with wrapper (0.96^{**}) and biological yield (0.96^{**}) were strongly positively correlated with yield without wrapper or net head yield. However Mean shoot mass and harvest index are positively correlated, they are poorly correlated with the net yield, but days to head initiation ($r=-0.77^{**}$), days to maturity ($r=-0.73^{**}$) and days to harvesting ($r=-0.57^{**}$) were highly negatively correlated to the total net head yield. Therefore Total fresh yield were significantly and positively correlated with all growth, yield and yield related traits with the

exception of shoot mass. This implies that improving any of these parameters may lead to the improvement in yield.

Generally, the correlation coefficients indicated in Appendix Table 8 clearly explained the pattern of interrelationship among the yield and yield attributes considered in the experiment.

Partial budget analysis

In this study, the costs of Nitrogen fertilizer and labor cost for transplanting and fertilizer application varied while other costs were constant for each treatment. In order to recommend the present result for end users, it is necessary to estimate the minimum rate of return acceptable to farmers in the recommendation domain. Based on partial budget analysis, the net benefit accrued from the experiment ranged from nitrogen application alone is birr 93498 to 112603 per hectare (Appendix Table 9) compared with non-application of nutrients which is birr 45135 per hectare. For the farmyard manure treatments alone net benefit ranged from birr 58774 to 76764 per hectare benefit. This is an indication of the level of profitability of the animal manure treatments.

The marginal rate of returns, which determines the acceptability of any treatment shows that treatments that receiving $235\ kg\ N\ ha^{-1}$ in combination with $6\ t\ ha^{-1}$ of FYM yielded good results of 2535.31% marginal revenue. However, the marginal rate of returns for the Nitrogen fertilizer alone was higher than those for the farmyard manure. All in all the highest net benefit 176058 birr was obtained from treatment combination of $235\ kg\ N\ ha^{-1}$ with $6\ t\ ha^{-1}$ FYM with a marginal rate of return 2535.31% but the lowest net benefit 76764 birr was obtained from the treatment combination of $59\ kg\ N\ ha^{-1}$ with $6\ t\ ha^{-1}$ FYM with a marginal rate of return of 71.16% only in one growing season (Appendix Table 9). This means that for every 1.00 birr invested for $235\ kg\ N\ ha^{-1}$ with $6\ t\ ha^{-1}$ farmyard manure input and its application in the field, farmers can expect to recover the 1.00 birr and obtain an additional 25.35 birr. Therefore the most attractive rates for producers with low cost of production and higher benefits in this case were $235\ kg\ N\ ha^{-1}$ with $6\ t\ ha^{-1}$ farmyard manure combination.

The marketable head yield was adjusted by 10% adjustment coefficient and the marginal rate of return (MRR) and net benefits are calculated by current fertilizer (Urea) was $8.50\ kg^{-1}$ and field price of cabbage was $3.00\ birr\ kg^{-1}$.

Summary and conclusions of the study are as follows:

The maximum yield achievement by crop relies on the application of the correct level of nutrients. In addition, especially for production of crop, the effect of fertilizer levels is important. Therefore, the present study was initiated to assess the effects of different levels of nitrogen and farmyard manure on yield and yield components of cabbage. Accordingly, five levels of N and four levels of FYM fertilizer were evaluated at Bore, southern Ethiopia in 5 X 4 factorial arrangements using randomized complete block design with three replications on a plot size of 3.6 m X 3 m per treatment unit. Cultivation aspects such as nutrient requirements are vital in maximization of cabbage head yields. It is therefore, important for the end user to determine the best combination of optimum nitrogen and organic manure (FYM) levels. Incorporation of FYM and nitrogenous fertilizer will improve yields of head cabbage.

Applied N fertilizer levels revealed highly significant differences ($P < 0.001$) on plant height, number of expanded true leaves, days to head initiation, days to maturity, average head height, head diameter, days to harvesting, untrimmed head weight, trimmed head weight, yield with wrapper, yield without wrapper and biological yield. But field stand count, shoot mass and harvest index were not influenced by the nitrogen fertilizer. FYM fertilizer application levels also revealed highly significant differences ($P < 0.001$) on plant height, number of expanded true leaves, days to head initiation, days to maturity, average head height, head diameter, days to harvesting, untrimmed head weight, trimmed head weight, yield with wrapper, yield without wrapper and biological yield. Similarly like nitrogen, FYM application did not influenced field stand count, shoot mass and harvest index of head cabbage.

The interaction effect between N and FYM fertilizer application rates highly significantly ($P < 0.001$) influenced plant height, number of expanded true leaves, days to head initiation, days to maturity, average head height, head diameter, days to harvesting, untrimmed head weight, trimmed head weight, yield with wrapper, yield without wrapper and biological yield per hectare. Field stand count, shoot mass and harvest index didn't show significant difference ($p > 0.05$) because of the application of N and FYM application rates. Highest untrimmed head and trimmed head weight was produced under all the N and FYM fertilizer rates. The untrimmed head weight (1870g and 1650g) was obtained by

application of N and FYM fertilizer at a rate of 235 kg N ha⁻¹ and 6t ha⁻¹ respectively. Similarly the trimmed head weight (1340g and 1030kg) was obtained by application of N and FYM fertilizer at a rate of 235 kg N ha⁻¹ and 6t ha⁻¹, respectively. In a similar way the interaction effect revealed highest untrimmed head weight (2290kg) obtained with treatment combinations of 235 kg N ha⁻¹+6 t ha⁻¹ over the control plot. As to the interaction effect of nitrogen and FYM on net or trimmed head weight highest result (1760kg) obtained with treatment combinations of 235 kg N ha⁻¹+6 t ha⁻¹ over the control plot. It can be concluded that different Nitrogen, FYM rate and their interaction have remarkable effect on yield of cabbage. From this study it is found that, highest head yield without wrapper per hectare of 72.36 t ha⁻¹ was observed in the combination treatment of 6 t ha⁻¹ FYM + 235 kg N ha⁻¹ fertilizer and the least yield of 19.15 t ha⁻¹ were observed in the untreated control. Therefore, these treatment combinations appeared promising for cabbage production under the study area. Our result of the study revealed that the combined application of Nitrogen fertilization and farmyard manure resulted in better performance in terms of improving total net head cabbage yield.

Based on partial budget analysis the highest net benefit 176058 birr was obtained from treatment combinations of 235 kg N ha⁻¹ with 6 t ha⁻¹ with a marginal rate of return of 2535.31%. Therefore the most attractive rates for the producers with low cost of production and higher benefits in this case were treatment combination of 235 kg N ha⁻¹ with 6 t ha⁻¹. However, as this is a one location and one season experiment the experiment has to be repeated over seasons and locations with consideration of additional varieties, soil type and economic feasibility to reach at convincing recommendation.

Mineral nitrogen from mineral solution fertilizers represents the easier available form of nitrogen compare recommended mineral fertilizers. Using organic manure plus inorganic solution fertilizers gave a significant effect on plant growth, heads yield, chemical constituents and mineral composition of broccoli. Organic manure enhances soil aggregation, aeration, water holding capacity and amended the root system by slow release flow of nutrients which in combination creates favorable conditions for root respiration, nutrients absorption, root and upper parts growth and yield quantity and quality. Organic manure increases the fertility and productivity of sandy soils. As far as the agronomic productivity is concerned, it would be difficult to make definite conclusion based on the research results of one season

and one location. Therefore cabbage growers at Bore and surrounding area need to apply farmyard manure of 6 ton in combination with nitrogen at 235 kg per hectare, in order to maximize the yield of head cabbage on the soils of study area. Generally due to high cost of fertilizer in the market, cabbage growers can combine the farmyard manure and inorganic nitrogen to reduce cost and since organic FYM releases both major and minor nutrients, farmers should embark on the use of FYM for effective growth and yield since it's found in their areas.

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Appendix Table 1. Linear Correlation Coefficient (r) for Yield and Yield Components of Head Cabbage

	T	R	PH	NELVS	HH	HD	HWUTR	HWTR	YLDRPR	YLDWRP R	BMY	HI
T	1.000	0.000 ^{ns}	0.762***	0.559***	0.207 ^{ns}	0.346*	0.367**	0.074 ^{ns}	0.748***	0.742***	0.748***	0.252 ^{ns}
R		1.000	0.452**	0.602***	0.339*	0.287*	0.161 ^{ns}	0.211 ^{ns}	0.318*	0.259*	0.318*	-.032 ^{ns}
PH			1.000	0.835***	0.371**	0.429***	0.410**	0.271 ^{ns}	0.776***	0.712***	0.776***	0.098 ^{ns}
NELVS				1.000	0.378**	0.327 ^{ns}	0.351*	0.307 ^{ns}	0.699***	0.648***	0.699***	0.113 ^{ns}
HH					1.000	0.847***	0.721***	0.732**	0.680***	0.652***	0.680***	0.112 ^{ns}
HD						1.000	0.743*	0.671**	0.706***	0.687***	0.707***	0.135 ^{ns}
HWUTR							1.000	0.903**	0.751***	0.764***	0.751***	0.303*
HWTR								1.000	0.602**	0.618**	0.602**	0.268*
YLDRPR									1.000	0.963**	1.000**	0.227*
YLDWRP										1.000	0.963**	0.466*
BMY											1.000	0.228 ^{ns}
HI												1.000

Where T= Nitrogen, R= Farmyard manure, PH=Plant height, NELVS= Number of expanded leaf, =Days to maturity, HH= Head height, HD= Head diameter, HWUTR=Head weight untrimmed, HWTR=Head weight trimmed, YLDRPR=Yield with wrapper, YLDWRP=Yield without wrapper, BMY=Biomass yield, HI=Harvest index, ns=non-significant difference, * indicates significant at 5%, ** indicates significant at 1%, *** indicates highly significant at 1%.