EFFECT OF IRRIGATION SCHEDULING AND NITROGEN FERTILIZER RATES ON GROWTH AND PRODUCTIVITY OF CABBAGE (*Brassica oleracea* L.Var. *Capitata)* AT BUYO KACHAMA KEBELE SEKA WOREDA JIMMA

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Effect of Irrigation Scheduling and Nitrogen Fertilizer Rates on Growth and Productivity of Cabbage (*Brassica oleracea* L.Var. *Capitata)* at Buyo Kachama Kebele Seka Woreda Jimma

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MSc THESIS APPROVAL SHEET

We, the undersigned, member of the Board of Examiners of the final open defense by Fasika Terefe have read and evaluated his/her thesis entitled "Effect of Irrigation Scheduling and Nitrogen Fertilizer Rates on Growth and Productivity of Cabbage (*Brassica oleracea* L. Var *Capitata*) at Buyo Kachama Kebele Seka Woreda Jimma" and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Science in **Agronomy.**

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BIOGRAPHICAL SKETCH

The author, Fasika Terefa Ayana, was born on February 10, 1985 at Nekemet town, East Wollega Zone of Oromia region. She attended her elementary school at Burqa Bekumsa (from 1-6), Junior secondary school at Biftu Nekemte (from7-8) and secondary school at Derge secondary(from 9-10). Following the completion of her secondary education, she joined Bako Agriculture, Technical and Vocational Educational Training College (ATVETC) in Diploma (10^{+3}), and after three years of working in East Wollega Zone, Gutogida Woreda agricultural office, graduated with B.Sc. Degree in horticulture in June 2010 at Jimma University. She was employed by Guto Gida Woreda Irrigation Office Authority and served the Bureau until she joined the graduate studies program of Jimma University College of Agriculture and Veterinary Medicine to pursue a graduate study leading to a Master of Science degree in Agronomy. She has one child.

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ABREVATIONS AND ACRONYMS

CSA	Central Statistical Authority
ETo	Evapo-Transpiration
FAO	Food and Agricultural Organization
Fc	Field Capacity
Irg	Gross Irrigation Requirement
Kc	Crop Coefficient
Irn	Net Irrigation Requirement
Kpa	Kilo Pascal
Pwp	Permanent Wilting Point
SDF	Statistical Division, Food and Agricultural Organization
Sws	Supply of Water System
t/ha	Ton Per Hectare
TAW	Total Available Water
WUE	Water Use Efficiency

Effect of Irrigation Scheduling and Nitrogen Fertilizer Rate on Growth and Productivity of Cabbage (*Brassica oleracea* L.Var. *Capitata)* at Buyo Kachama Kebele Seka Woreda Jimma

ABSTRACT

A field experiment was conducted to investigate the effect of irrigation schedules and nitrogen fertilizer application rate on growth and productivity of cabbage. The study was conducted from November 2015 to March 2016 at Buyo Kachama Kebele Seka woreda Jimma, Western Ethiopia. Three irrigation scheduling (3 days, 6 days and 9 days) and five nitrogen fertilizer levels (0, 23, 46, 69 and 92 kg/ha) were used. The experiment was laid out in Randomized Complete Block Design (RCBD) in 3x5 factorial arrangements with three replications and one farmer practice. Copenhagen market variety of cabbage was used for this experiment. Results indicated that marketable yield, unmarketable yield, total head yield, whole fresh weight, head diameter, head height, plant height and plant spread were significantly($P<0.001$) affected by the interaction effect of irrigation scheduling and nitrogen fertilizer rates. The highest Dry matter(7.36%) was recorded at 92kg ha^{-1} nitrogen fertilizer rate and 9 days irrigation schedules, marketable yield(64.5 t/ha), lowest unmarketable yield(7t/ha), highest total head yield(71.52 t/ha), biggest whole fresh weight(5.73kg/plant), biggest head diameter(17.43cm), highest head height(19.67cm), highest plant height (24.65cm),wider plant spread(38.77cm), highest water use efficiency(152.47kg$ha^{-1}mm^{-1}$) and nitrogen recovery(89.9 %) *was recorded at 9 days irrigation schedules and 23 kgha^{-1} nitrogen fertilizer rate which is statically similar with 9 days irrigation scheduling and 46 kg/ha nitrogen fertilizer rate. On the other hand harvest index significantly affected by nitrogen fertilizer rate and irrigation scheduling but not by its interaction effect. Highest harvest index (60%) recorded at 6 days irrigation scheduling and 60.7% at 92kg ha^{-1} nitrogen fertilizer rate. As well as outer leaf number was not affected by interaction effect of irrigation scheduling and nitrogen but it was affected by nitrogen fertilizer rate. Higher outer leaf number was obtained at control nitrogen fertilizer rate (18.66) which is statically similar with 23 kgha^{-1} nitrogen fertilizer rate (18.66). Yield and yield components were better recorded at treatment combinations of 3, 6 and 9 days irrigation scheduling combined with 92 kg N ha^{-1} compared to the traditional farmers irrigation and fertilizer management. However, further investigations may be suggested to be carried out at different seasons of the year, location, soil type, cabbage varieties and different farmer practice so as to come up with precise and comprehensive recommendation.*

Key words: Yield, Water Use Efficiency, Nitrogen Recovery.

1. INTRODUCTION

Cabbage (*Brassica oleracea var. capitata* L.) belongs to the family cruciferae and it is biennial crop with a very short stem supporting a mass of overlapping leaves to form a compact head. It originated from wild non-headed type ‘cole wart’ (*Crambe cordifolias*) from Western Europe and Northern Shore of Mediterranean (Semuli, 2005). It has been domesticated and used for human consumption since the earliest antiquity. It is cool season crop that is very popular with gardeners and commercial producers.

Cabbage is an excellent source of vitamin C and vitamin K, containing more than 20% of the Daily Value (DV) for each of these nutrients per serving (USDA, 2014). Cabbage is also a good source (10–19% DV) of vitamin B6 and folate, with no other nutrients having significant content per 100 grams serving table. Basic research on cabbage phytochemicals is ongoing to discern if certain cabbage compounds may affect health or have anti-disease effects. Such compounds include sulforaphane and other glucosinolates which may stimulate the production of detoxifying enzymes during metabolism (Dinkova and Kostov, 2012). Studies suggest that cruciferous vegetables, including cabbage, may have protective effects against colon cancer. According to Tse *et al*., (2014), purple cabbage contains anthocyanins which are under preliminary research for potential anti-carcinogenic properties. Cabbage is also a source of indole-3-carbinol, a chemical under basic research for its possible properties (Wu, *et al*., 2010).

Total world production of all brassicas for calendar year 2012 was 70,104,972 metric tons (68,997,771 long tons; 77,277,504 short tons). The nations with the largest production were China, which produced 47 percent of the world total, and India, which produced 12 percent. China and India used a surface area of 980,000 hectares (2,400,000 acres) and 375,000 hectares (930,000 acres), respectively, to grow these crops; the total global surface area used for cabbage and related *Brassica* crops in 2012 were 2,391,747 hectares (5,910,140 acres). The largest yields were from South Korea, which harvested 71,188.6 kilograms per hectare, Ireland (68,888.9 kg/ha), and Japan (67,647.1 kg/ha) (FAO, 2015). The five-cabbage producing African countries are Kenya, Egypt, Ethiopia, Nigeria and South Africa and these five countries have maintained the dominance of the sector throughout this period. Ethiopia counted for 12% of the total production in Africa (SDFAO, 2010). Area, production and yield of head cabbage in Ethiopia in 2015/2016 were 7,197.70hectares, 463,17.72tons and

6.45ton/ha respectively, in Jimma Area, production and yield of head cabbage was 143.40 hectare, 10,11.84tons and 7.1ton/ha (CSA, 2016).

In Ethiopia, where the amount, timing and distribution of rain fall is irregular, use of irrigation would significantly improve and raise the level of production (Haile, 2014). The amount of water required by plants and the timing of irrigation are governed by prevailing climatic conditions, crop and stage of growth, soil moisture holding capacity and the extent of root development as determined by crop type, stage of growth and soil (Kadyampakeni, 2013). Thus, the amount of water required by plants varies from place to place. Crop yield is affected by different factors other than water such as crop variety, soil salinity, pests, diseases and agronomic practices. Also, improved water management would help in coping with increasing demands for water by industrial and urban users and the agricultural sector (Fraiture and Wichelns, 2010) there by making water available for environmental and other uses (Fraiture *et al*., 2010).

Irrigation scheduling is a critical management input to ensure optimum soil moisture status for proper plant growth and development as well as for optimum yield, water use efficiency and economic benefits. Therefore, it is essential to develop irrigation scheduling strategies under local climatic conditions to utilize scarce water resources efficiently and effectively (De Fraiture *et al*., 2010).

Cabbage water requirements are approximately 440mm depending on climate and length of growing season (http://www.starkeayres.co.za/com_variety_docs/Cabbage-Production-Guideline 2014.pdf). The crop transpiration increases during the crop growing period with a peak toward the end of the season. Depending on climate, crop development and soil type, the frequency of irrigation varies between 3 and 12 days. If water supply is limited, early irrigations should not be practiced. Water savings should preferably be made in the beginning of the crop growing period (Nortje and Henrico, 1988).

Cabbage has high requirements for all nutrients, especially nitrogen. Cabbage demands 130 to 310 kg/ha nitrogen for achieving high yield (Lešić et.al. 2004, Sanderson and Ivany, 1999) and according to Richard *et al,* (2016) 375kg/ha nitrogen fertilizers gave maximum head yield. Adequate application of nitrogen fertilizer promotes vigorous vegetative growth and dark green color of cabbage (Ware and McCollum, 1980; Peck, 1981; Hadfield, 1995).

Nitrogen is important in the formation of chlorophyll and is also a component of proteins. Lack of nitrogen causes slow, spindly growth and pale foliage, resulting in limited production (Hadfield, 1995). In Ethiopia application of nitrogen fertilizer averagely 130kg/ha, in Oromiya regain 110kg/ha (CSA, 2012)

Cabbage is more susceptible to water stress and nitrogen deficiency. Improper irrigation management practices cause not only wastage of scarce water resources but also decreases crop yield, quality, water use efficiency and economic return as well as leads to water logging and salinity which can be partly corrected by expensive drainage system (Himanshu *et al.,* 2012).

For cabbage production in dry area or in the summer season farmers use irrigation. Most of them are producing different horticultural crops. From this cabbage is one of most needed crops around Jimma area. But the production of these crops is less because from sowing up to harvesting it needs better crop management as well as protection from different disease and insects attack. For these reason the price of these crops is very high in winter as well as in summer (Agricultural Office of Jimma zone, 2015).

During winter season Farmers of Jimma area irrigate their crop land on average once per week. These are done if there is no rain fall and if the environmental condition is warm and dry as well as by seen the moisture content of the soil by rubbing the soil between the two fingers of their thumb and the second finger. According Extension workers of Jimma Zone, 2015 says that farmers of Jimma area apply fertilizer which is not recommended and most of them do not apply fertilizer to cabbage crops, other farmers apply different farmyard manure, cow dugs and different crop residues which is collected from their houses. Some farmers apply by mixing UREA and DAP fertilizer by split application but they cannot use the recommended of fertilizer application rate. The area cultivated by cabbage in Jimma zone is 23,938ha. From these the yield is 219,165.7 tones from one hectare the farmers can get 9.1tones which is below the recommended.

Irrigation scheduling is one of the factors that influence the agronomic and economic viability of small farms. Fertility of most Ethiopian soils has already declined due to continuous cropping, abandoning of fallowing, reduced use of manure and crop rotation (Haileslassie *et al*., 2005; 2006 and 2007). In Ethiopia, national yield and variety trials data over several locations on different crop species clearly indicated that soil nutrient stress is the most significant factor influencing yield gap (Tamirie, 1989).The use of animal manure and crop residues for fuel and erosion coupled with low inherent fertility are among the main causes for decreasing soil fertility (Taye *et al*., 1996; Tilahune *et al*., 2007). Jimma is the area with high rain fall. But, during winter season rain fall of the area is erratic and cannot fulfill crop requirements. In summer season the rain fall is high and cabbage is very susceptible for different diseases as well as the high amount of water causes splitting the cabbage head. The availability of cabbage in the market is low as compared to winter season and is mostly needed as a fastening food. Farmers in these areas have low knowledge of timely and optimum application of irrigation. In addition, the amount of N fertilizer needed for optimum production of this vegetable is also context specific and the current recommendation is generalized. Considering the above facts, the present investigation was undertaken based on the following objectives.

Objectives

- To analyze effect of irrigation schedules and optimum water application based on crop water requirements.
- To identify effects of different levels of nitrogen fertilizer on growth and production of cabbage crop.
- To determine the optimum amount of water and nitrogen rate for cabbage production for the study.

2. LITERATURE REVIEW

2.1 Description and Origin of Cabbage

Cabbage (*Brassica oleraceae. var capitata*), is also known as cole crops. It belongs to family Brassicaceae (or Cruciferae) and generally referred as Brassicas. It is important groups of crop worldwide. It is originated from Western Europe and Northern Shore of Mediterranean region where it has been grown for more than 3000 years. It has chromosome number 2n=2x=18 (Ijoyah *et al*., 2001). It is dicotyledonous biennial crop, but it grows as an annual. In the first season growth, it produces the head and in the second season it produces seeds. Cabbage form several different head shapes: pointed conical, or oblong, round or bell shaped or drummed shaped. Cabbage generally classified as headed which is round, oval or flat. Chinese head cabbage is oval and flat, moreover it is loosely formed and light in weight. Head formation in cabbage is quantitative trait controlled additively with low dominance effect. It is only head cabbage that changes in leaf shape becoming wider because of the shorter petiole length with increasing leaf position and thus cabbage acquired the developmental change in leaves. Cabbage has been domesticated and used for human consumption since the earliest antiquity (Semuli, 2005). The genus Brassica includes about 100 species majority of which are native to Mediterranean region. The crop is attributed to the Mediterranean center of origin (Rai and Asati, 2005). It is widely grown as cool-season crop and is very popular with gardeners.

2.2 Nutritional Importance of Cabbage

A 100-g edible portion of cabbage contains 1.8 g protein, 0.1 g fat, 4.6 g carbohydrate, 0.6 g mineral, 29 mg calcium, 0.8 mg iron and 14.1 mg sodium (Singh and Naik, 1988). Moreover, it is a rich source of vitamins A and C (Prabhakar and Srinivas, 1990; Tiwari *et al.,* 2003). It may be served in slaw, salads or cooked dishes (Andersen, 2000). In order to maintain or even improve cabbage production, some factors have to be considered. Correct cultural practices such as adequate application of fertilizers (Everarts, 1993a) and optimum plant population have to be adhered to in order to obtain good yields in cabbage production (Singh and Naik, 1988; Lecuona, 1996; Singh, 1996; Parmar *et al*., 1999; Sandhu *et al.*, 1999; Kumar and Rawat, 2002).

2.3 Cabbage Production in Ethiopia

The five-cabbage producer of African countries are Kenya, Egypt, Ethiopia, Nigeria and South Africa and these five countries have maintained the dominance of the sector throughout this period. Area production and yield of cabbage in Ethiopia in 2014/2016 were 1989 hectares, 11765 tons and 5.9 t/ha, respectively. In 2008/2009 it grew to 3399 hectares, 24133.4 tons and 7 t/ha respectively. In Oromia, regional state the area covered by head cabbage in year 2015/2016 was 2188.9 ton/ha while the production was 15,601.9ton and the yield is 7t/ha (CSA, 2015).

2.4 Agronomic Practice of Cabbage Production

Cabbage grows well on wide range of soil. But it requires well drained sandy loam soil, with pH of 6-6.5, rain fall of 700-900mm and 17-24^{0}c. Water logging is unsuitable for cabbage production. It is propagated by seed and system of planting is transplanting. It requires 0.6cm by 40cm between rows and plants. Fertilizer interval should be 5-7 days. Its days to maturity are 80-100days. In Ethiopia, its productivity is 25-30t/ha when improved practices are followed and 7t/ha when grows conventionally at farmer's level (Simret *et al*., 1994).

2.4.1 Nutritional requirement of cabbage

For optimum plant growth, nutrient must be available in sufficient and balanced quantities for better performance of crop. Soil contains natural reserve of plant nutrients, but these reserves are largely in forms unavailable to plants, and only a minor portion is released each year through biological activities and chemical processes. Therefore, fertilizers are designed to supplement the nutrients already present in the soil. The type of fertilizer and quantity to apply depends on soil type, initial nutrient reserves in the soil and yield level. (Zhibin *et al*., 2011).

Cabbage is one of the most important, high nutritive and palatable leafy vegetables. It is a rich source of protein, minerals and vitamin A (Uddin *et al*., 2009). It has some medicinal value as it prevents constipation, increases appetite, speeds up digestion and is very useful for diabetic patient. Fertilizer enhances plant growth by providing amendments to the soil via various macro and micronutrients. The fertilizer application for cabbage should ensure adequate levels of all nutrients. Optimum fertilization is required to produce top quality and high yields while a lack of essential fertilizers will stunt its growth, leading to undersized and poorly developed heads.

Cabbage is well known to be an exhaustive crop and has the capacity to absorb higher amount of nutrient from soil. The supply of proper nutrient must be ensured during its cultivation, which is related to the judicious application of fertilizer. In the upland field, cabbage yields were high when chemical fertilizers were applied (Kamiyama *et al*., 1995). The crop production system with high yield targets cannot be sustainable unless nutrient inputs to soil are at least balanced against nutrient removal by crops (Jahiruddin and Rijpma, 2004).

The quantity of fertilizer requirements in cabbage depends on fertility of status of the soil which is determined by soil testing. Cabbage requires large amounts of fertilizer .as it benefit from higher levels organic matter, it is suggested that animal manure (if available) be the basis of the fertilizer program. The most important nutrient for cabbage is nitrogen, phosphorus, potassium and sodium molybidate. In cabbage fertilizers (especially nitrogen) promote rapid growth, high yield and high produce quality. High value crops such as cabbage, proper nutrition is important to produce a high yield and good quality. There is a correlation between the amount of nitrogen applied and quality of cabbage. Cabbage head will not form if there is shortage of nitrogen. On the other hand, excess nitrogen may cause the formation of loose heads with internal decay. The demand for phosphorous is greater during head formation and shortage will result in purple leaves. Potassium deficiency can also result in necrosis and reduce head quality but an excess of potassium can cause cracked heads. Cabbage also requires sulfur, magnesium and boron. High temperature causes nutrients, especially nitrogen; to be available to the growing plants much quicker and will result in high quality yields Semuli, (2005). A side dressing of nitrogen is desirable after the head has formed to about half the size to maturity.

2.4.2 Cabbage crop response to nitrogen fertilizer

Higher levels of nitrogen have often been found to induce optimum yields in *Brassica* vegetables. Zebarth *et al*., (1991) observed a positive yield response up to 500 $kg \cdot ha^{-1}$ N, but that percentage nitrogen recovery was lower at the higher rates (± 30% lost at 500 $kg \cdot ha^{-1}$).

Peck (1981) reported increased yields of cabbage heads to about 40 tone/ha fresh mass more than plants grown without nitrogen fertilizer.

Parmar *et al.* (1999) recorded higher yields in cabbage with increased nitrogen rates. The application of 200 $kg \cdot ha^{-1}$ N produced significantly higher yield over 150 kg ha^{-1} N but at par with 250 kg ha^{-1} N. This was attributed to the fact that higher nitrogen levels favored the growth of plants with larger leaf area and it was more usefully utilized in head formation. Similar observations on cabbage were made by Ghantis *et al.* (1982), where yield contributing characters such as head diameter and gross mass of heads and number of marketable heads increased with increase in the levels of nitrogen up to 200 kg ha^{-1}. Gupta (1987) observed significantly higher cabbage yields at 150 $kg \cdot ha^{-1}$ N than yields at 0, 50 and 100 $kg \cdot ha^{-1}$ N yet at par with yield at 200 $kg \cdot ha^{-1}$ N. Increase in yield was attributed to increase in head mass.

Brussels sprout yields increased to 33.5 t ha^{-1} as nitrogen fertilizer was increased up to 90 kg ha^{-1}. It was, however, observed that, even though yields increased significantly with increasing nitrogen fertilizer rate, the midrib NO3-N levels did not always parallel these yield increases. Cauliflower yields were also observed to increase (21.3 t ha^{-1}) as the nitrogen rates increased to 140 kg ha^{-1}. As the midrib NO3-N levels increased, it was observed that there was an increase in yield which suggested a close relationship in cauliflower between midrib NO3-N levels and yield.

Everaarts and De Moel (1998) reported increasing uniformity with increasing amounts of nitrogen applied. In cabbage production uniformity of heads is important. Increase in relative core length was observed when nitrogen application rate increased, whereas dry matter content of the heads decreased. This was associated with softer head tissue at higher nitrogen availability, thereby having less physical resistance to stalk elongation. The lower the relative core length, the better the head quality (Aalbersberg and Stolk, 1993).

Peck (1981) observed decreases in percent dry mass of the heads, increased number of burst heads and increased tip-burn in the heads with increasing fertilizer nitrogen rate. It was therefore concluded that high nitrogen fertilizer decreased the quality of cabbage heads.

To produce optimum yields of good quality cabbages, often high amounts of nitrogen fertilizer are applied. In reality, the amount of nitrogen fertilizer used is probably higher as farmers may apply more fertilizer than recommended to secure yields (Classens, personal communication, 2004). Nitrogen produces reliable and optimal yield and quality of vegetables. It is however, the most difficult element to manage in a fertilization system in order to ensure an adequate, yet not excessive, amount of available nitrogen within the rhizosphere from planting to harvest (Peck, 1981).

Assessing of cabbage total yield, marketable yield, weight per head, head density, and head size for two season by Westerveld *et al*., (2003) total yield showed a peak at 265 kg N ha-1 Head size and weight per head increased with increasing N rate only in, reflecting differences in yield. Days to maturity decreased with increasing N rate reaching a minimum at 245 and 226 kg ha-1. Nitrogen rates above recommended levels are beneficial in maximizing cabbage yields in wet years and minimizing days to maturity. Richards *et al*., (2016) say cabbage yield is higher at 375 kg nitrogen per hectare and get a total yield of 103.9ton/ha.

2.5 Land productivity with irrigation

Ethiopia has 12 river basins with an annual runoff volume of 122 billion m^3 of water and an estimated 2.6 - 6.5 billion m^3 of ground water potential. This corresponds to an average of 1,575 m^3 of physically available water per person per year, a relatively large volume. However, due to large spatial and temporal variations in rainfall and lack of storage, water is often not available where and when needed (IWMI, 2007). Meanwhile, irrigation is expected to reduce the impact of erratic rainfall on household income fluctuations, promote intensive land use therefore reducing the risk of crop failure (Rahmato, 1999). Likewise, research report by MoWR (2001) suggested that irrigation have positive impacts on small scale producers in reducing poverty and increasing food self-sufficiency and farming equipment.

A report by Ripple (2010) indicated that through intensified production and reduced losses, irrigation agriculture could reduce losses and contribute more than 20% to 300% compared to non-irrigated agriculture. Likewise, Fitsum *et al*. (2011) indicated that irrigation could generate about 120% times higher income than rain fed based vegetable farm. Further, research report by MoWR (2001) indicated that irrigation have positive impacts on small scale producers in reducing poverty and increasing food self-sufficiency and farming equipment.

Major vegetables grown in Ethiopia includes lettuce, head cabbage, Ethiopian cabbage, tomatoes, green peppers, red peppers, Swiss chard, potatoes, beetroot, garlic, snap beans, shallot, carrot and onion (CSA, 2012). Vegetables serve as source of income, food and feed. According to (EARO, 2000), vegetables have high nutritive value compared to cereals. Furthermore, vegetables can generate high income for the farmers because of high market value and profitability (Kumilachew *et al.,* 2014). Moreover, vegetables' leftovers are important sources for animal feed in both urban and rural areas In Ethiopia, about 97% of the vegetables come from small scale farmers. But the problems with these farmers are that they undervalue both economic and nutritional value at farm level. Therefore, the farmers mainly emphasize on production of cereal crops with little addition of vegetables (SNV, 2012; Miklyaev and Jenkins, 2012; Kumilachew *et al*., 2014). This is confirmed by an enormous decline in both production area and yield. For instance, area from year 2012 to 2013 and from 2013 and 2014 declined by -16% and -22%, respectively and the yield declined by -15% for the two years' interval (CSA, 2014).

2. 6 Response of Cabbage to Irrigation Scheduling

Cabbage as a vegetable requires water throughout its growing season. Unfortunately, the amount and distribution of rainfall is seasonal and at times erratic. Smittle *et al*. (1994) found that cabbage yield was highest when irrigation was applied at 25 kPa soil water tensions, as compared to 50 or 75 kPa. Drew (1966) reported higher cabbage yield with irrigation at 12.5% than at 25, 50, or 75% available soil moisture content. Using sprinkler irrigation system, Sanchez *et al.,* (1994) found that cabbage production was optimized when crops were irrigated for evapo-transpiration (ET) replacement while both deficit and excess irrigation reduced yield.

Kadyampaken, (2013) compare three irrigation scheduling (F1-Irrigated twice a week, F2-Irrigated once a week and F3-Irrigated once a fortnight) for two areas and two years 2006 and 2007. The result shows that among tested scheduling yield was higher at F1or irrigated twice a week that is 32.9 and 23.0 t ha^{-1} for two areas respectively. Imtiyaz *et al.* (2000) examined the effect of irrigation scheduling using 18 mm of water in each irrigation when cumulative pan evaporation reached 11, 22, 33, 44 and 55 mm and found that irrigation at 11 mm of cumulative pan evaporation had the highest cabbage yield.

Leskovar, (2014) says that deficit irrigation on cabbage growth, physiology and yield has different responses. Deficit irrigation at 75% ETc had little influence on plant size, leaf pigment content, leaf characteristics, leaf gas exchange, head weight and size, except for a moderate reduction in marketable yield. However, dry weight of marketable heads was not significantly different between 100 and 75% ETc irrigation. Since dry weight percentage increased under deficit irrigation, it suggests that most yield reduction under deficit irrigation is related to water content.

2.7 Response of Cabbage to Interaction of Irrigation Schedules and Nitrogen Fertilizer

Cabbage needs both water and nitrogen fertilizer simultaneously because both nitrogen and water among important factor for yield and growth production. The effects of nitrogen rates and irrigation levels on growth, yield and nutrient contents of cabbage with application of the average soil water suction of the surface 40 cm of the soil approached 0.8, 1.6 and 3.6 bars, respectively and Nitrogen as ammonium nitrate was applied at rates 0, 50, 100, 150, 200 and 250 kg per hectares. Both of nitrogen application and irrigation significantly increased yield. Application of nitrogen up to 200 kg per hectare steadily increased the cabbage yields at I-1 and I-2 irrigation levels whereas up to 150 kg N per hectare at I-3 more than 200 or 150 kg N per hectare depends on irrigation treatments decreased yield. A significant nitrogen-irrigation treatment interaction reflected the lack of response to nitrogen by the cabbage yield under inadequate irrigation treatments (Padem and Alan, 1995).

According to Mostafa and Zohair (2013) the application of 350 kg ha^{-1} of N fertilizer had recorded significantly higher total and marketable heads yield over 106.5 and 125 %, respectively, as compared with 150 kg ha-1 level. Also, obtained results illustrated that split application of N fertilizers up to 20 equal doses fertigation strategies through drip irrigation, significantly, increased all the outer leaves, heads and head’s mineral contents, total and marketable head yield ha-1 traits of cabbage plants.

2.8 Water Use Efficiency

At plant level, the ratio of plant biomass over the evapo-transpired water is used to define WUE and is considered a measure of plant's efficiency in using water. At crop level, WUE is calculated as the transformation efficiency of water, through the cultivation system into yield, according to the formula:

$$\text{Water use efficiency} = \frac{\text{biomass}}{\text{E} + \text{T} + \text{losses}}$$

Where, T = transpiration, E = evaporation losses = amount of water lost at any level of the process. As it is difficult to separate E and T components, they are usually included in the term ET.

Water use efficiency can be improved by modifying both terms of the ratio. Agronomic techniques aimed at reducing water losses (at irrigation, field or plant levels) and effectively conveying water to the root zone will increase WUE. Similarly, any agronomic practice that will increase crop yield will ultimately enhance WUE. Other criteria to improve WUE may involve controlling physiological processes that affect plant transpiration and yield. Abscisic acid (ABA) mechanism of perception and signaling has greatly advanced. This will likely open new avenues for developing commercial products that modulate/control ABA action to improve plants WUE (Weiner *et al*., 2010). It has been recently demonstrated that over expression of *NCED*, a key gene in ABA biosynthesis, may cause stomata closure and reduce transpiration without affecting CO_2 assimilation and biomass accumulation (Thompson *et al*., 2007).

2.9 Crop Water Requirements versus Irrigation Requirement

Crop water requirement refers to the water used by crops for cell construction and transpiration, the irrigation requirement is the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirement. If irrigation is the sole source of water supply for the plant, then the irrigation requirement will be at least equal to the crop water requirement, and is generally greater to allow for inefficiencies in the irrigation system. If the crop receives some of its water from other sources (rainfall, water stored in the soil, underground seepage, etc.), then the irrigation requirement can be considerably less than the crop water requirement. The Net Irrigation Requirement (IRn) does not include losses that are occurring in the process of applying the water. IRn plus losses constitute the Gross Irrigation Requirement (IRg).

It is important to realize that the estimation of crop water requirements is the first stage in the estimation of irrigation requirements of a given cropping program. Hence the calculation of crop water requirements and irrigation requirements must not be viewed as two unrelated procedures.

Hess (2005) defined crop water requirements as the total water needed for evapo-transpiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. FAO (2005) defined crop water requirement (CWR) for a given crop as:

$$CWR_i = \sum_{t=0}^{T} \left(\mathrm{Kc_i} \times \mathrm{Eto_i} - \mathrm{P_{effi}} \right) \text{ Unit: mm}$$

Where kci is the crop coefficient of the given crop i during the growth stage t and where T is the final growth stage. Each crop has its own water requirements. Net irrigation water requirements (NIWR) in a specific scheme for a given year are thus the sum of individual crop water requirements (CWRi) calculated for each irrigated crop i. Multiple cropping (several cropping periods per year) is thus automatically taken into account by separately computing crop water requirements for each cropping period. By dividing by the area of the scheme (S. in ha), a value for irrigation water requirements is obtained and can be expressed in mm or in m^3/ha (1 mm = 10 m^3/ha).

FAO (1992), Smith *et al*. (1991) and Smith (1992) reported that CROPWAT is meant as a practical tool to help agro-meteorologists, agronomists and irrigation engineers to carry out standard calculations for evapo-transpiration and crop water use studies, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rain fed conditions or deficit irrigation. Broner and Schneekloth (2003) reported that water requirements of crops depend mainly on environmental conditions. Plants use water for cooling purposes and the driving force of this process is prevailing weather conditions. Different crops have different water use requirements, under the same weather conditions. If there is rain fall there should be installed rain gauge on the experiment area.

2.11 Maturity, Harvesting Marketing Yield and Quality of Cabbage

The heads should be a cooler typical of the cultivar (i.e. green, red, or pale yellow-green) firm, and heavy for the size and free of insect, decay, leafy head and another defect. The harvest cabbage should be graded as marketable and non-marketable. The marketable sizes are those with head, minimum head weight of 0.45 kg, and non-damage to the edible portion of the plant. Whereas non-marketable sizes are; those that did not headed, head small in size and weight, head burst or split, damage by insect or disease, miscellaneous categories in which some essential quality for marketable was lacking (NAARR, 1986). Westerveld *et al*., (2003) also noted that a cabbage heads which lacking (split), rotten and non-headed are considered as unmarketable. When cabbage does not form, this condition is called blindness and can arise due to excess nitrogen to form more leaves than are loosely held and do not make a head.

Weed is also the main problem in cabbage production. Weeding earlier before it harms the plant can increase yield. Most of weed management can be carried out by hand and also at time of hoeing. Hoeing is the most important intercultural practice which helps the crop well aerated and also weeds control. Crop protection also has to be considered in cabbage production. Cabbage can be affected by disease such as black rot, club root, turnip mosaic virus, sclertiniarit and pests such as cut warm, aphids, cabbage white butter fly, bud arm and others pests(More,2005).

3. MATERIALS AND METHODS

3.1 Description of Study Area

The experiment was carried out at Buyo Kacham kebele (13.50 ^{0}N latitude and 38.24 ^{0}E Figure 1), Seka woreda, Jimma zone, on farmer's farm from November 10, 2015 up to March 10, 2016. Seka Chekorsa district is located at 375 km south west of Addis Ababa. It is situated at an altitude of 2000 meters above sea level. The district receives rainfall, about 1543.5mm per annum. The average minimum and maximum daily temperatures of the area are 8.1 ^{0}C and 30.5 ^{0}C, respectively. The characteristic of the soil is clay loam soil (Table 1). Generally, this soil is fertile for cabbage production.

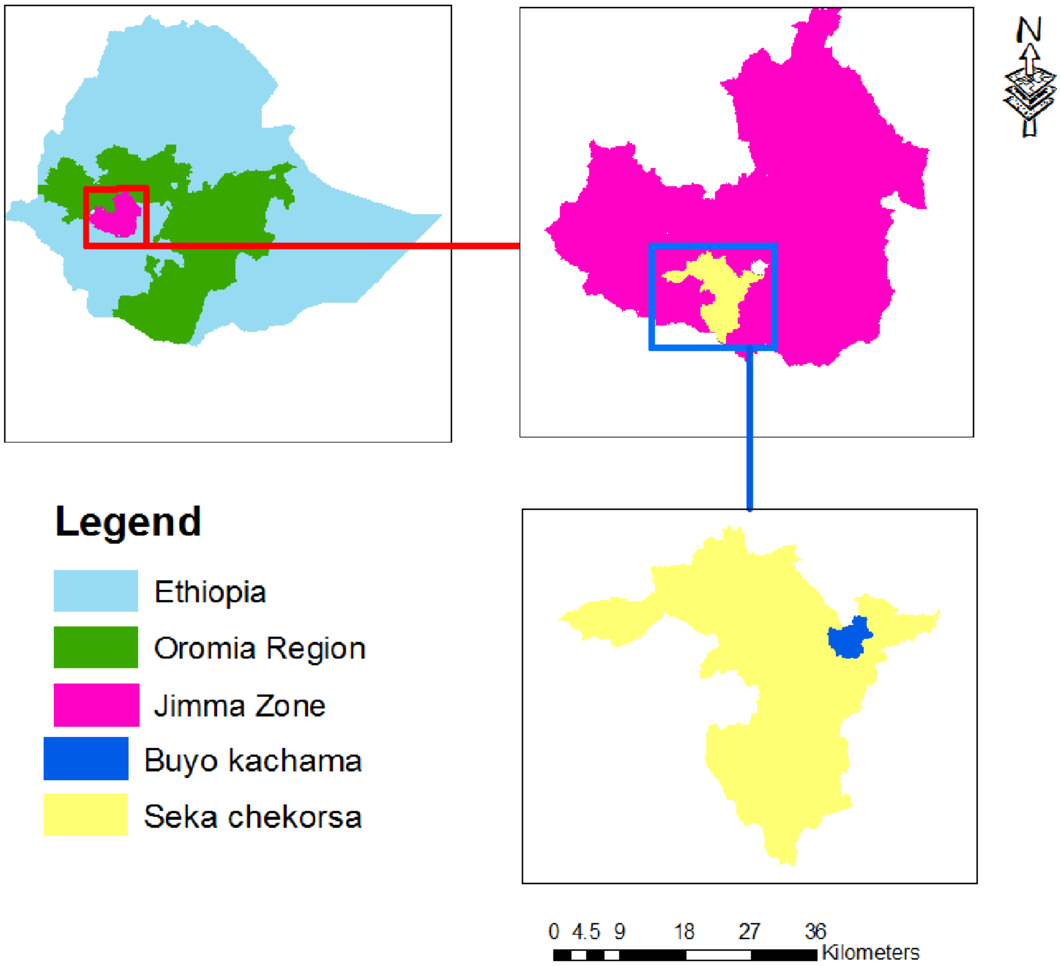

Figure 1 Location map of the study area

Table 1 Physical and chemical properties of soil at the experimental site

Parameters	Soil properties
% OM	7.40
% Total Nitrogen	0.37
pH	7.6
Available P in ppm	6.51
Texture	
% sand	13.50
% silt	32.00
% clay	54.50
Class	Clay Loam
Field Capacity (%) (0.33bar)	40.22
Permanent Wilting Point (%) (15 bar)	22.83

3.2 Experimental Material

The superior quality and high yielding cabbage Copenhagen variety was used. It was the most popular and reliable early round headed cabbage. This variety was widely adapted and requires 80-90 days maturity after transplanting. In Ethiopia, it was well grown at an altitude of 1500-3000 m.a.s.l (Girma, 2002). Seed of the variety had 99% purity and 85% germination percentage, with validity till 2017. Seeds were kindly supplied by from Melko research center Jimma, Ethiopia. Urea and 100kg/ha TSP were also purchased and used from Melko research center. Irrigation water was used from Gibe River of Saka woreda. The water quality of the river has the potential to be used as source of irrigation water.

3.3 Experiment Design

The field trial was established in a factorial experiment as Randomized Complete Block Design (RCBD) with three replications. Sowing was done on 10, November 2015 in Jimma, Seka Chekorsa Woreda and the experiment was started after transplanting to the main field. Two factors were considered in this experiment, these were irrigation scheduling and nitrogen fertilizer rate. By using cropwat version 8.0 software we estimated the amount of water required by cabbage crop to be 469.1mm $ET_{c.}$ But, the area received 260.9 mm during the crop growing season. To fill the amount of water required by the crop, the difference, 208.2 (469.1 – 260.9 = 208.2, table 2) was supplied as irrigation on three, six and nine days' interval. Based on this calculation, the crops received 11.73, 23.46 and 35.19 mm, respectively for each irrigation schedules.

The second factor which was nitrogen fertilizer was set at five levels, level 1 (0 N kg/ha), level 2 (23 N kg/ha), level 3 (46 N kg/ha), level 4 (69 N kg/ha), level five (92 N kg/ha). Depending on the availability of rain, farmers irrigate their cabbage once a week with a maximum of three liters per plant. As a practice, they also fertilize their farm land using different farm yard manure and/or residues. A combination of this farmer practice was used for comparison but was not included in the analysis. The experiment was set up as 3*5 factorial arranged in Randomized Complete Blok Design (RCBD) with three replications and one farmer practice. Thus, there were 16 treatment combinations (Table 3). Spacing of 60 × 45 cm was used (Thamburaj and Sigh, 2004; Singh *et al.,* 2004).

Table 2 Rain fall of Seka Chekorsa woreda from 1995-2015 and 2015/2016

Month	Rain fall (mm)
November	117.7
December	104.4
January	29
February	9.8
Total	260.9

To calculate effective irrigation rainfall=ET_c-Rainfall (http://www.fao.org/docrep/s2022e/s2022e08.htm)

=469.1mm - 260.9mm

=208.2mm

The plot size was 2.40m*2.25 m= 5.4 m^2 each plot there was 20 plants. The two outer rows of the plot were treated as border while the two middle rows in each plot would regard as experimental rows. The distant between each plot was one meter and the distance between the block was two meter and the total experimental area covers 467.25m^2.

Table 3 Treatments combination of irrigation schedules with fertilizer

Days of application irrigation	Nitrogen fertilizer level (kg/ha)	Treatment combination
3 days' interval	0	3 days x 0 kg
	23	3 days x 23 kg
	46	3 days x 46 kg
	69	3 days x 69 kg
	92	3 days x 92kg
6 days' interval	0	6 days x 0 kg
	23	6 days x 23 kg
	46	6 days x 46kg
	69	6 days x 69 kg
	92	6 days x 92 kg
9 days' interval	0	9 days x 0 kg
	23	9 days x 23 kg
	46	9 days x 46 kg
	69	9 days x 69 kg
	92	9 days x 92 kg
Farmer practice	Farm yard manure and cow dung	Farm yard manure and cow dung with 7 days

NB:- The amount of water used for 3 days interval is 11.73mm, for 6 days interval 23.46 mm, for 9 days interval 35.19 mm and for farmer practice 60 liters per plot.

3.4. Experimental Procedures

3.4 .1 Crop

Seedlings of the selected cabbage variety (*Brassica oleracea* L. var. *captata*) were raised in the seed bed one month before the actual transplantation (November 07, 2015). Thirty days after seeding (11 December, 2015), healthier and uniform seedlings were transplanted on a field at spacing of 60cm by 45cm. Thus, the unit plot accommodated a total of 20 plants. The seedlings were watered immediately after transplantation at field capacity. Counting of watering days stared from the day on which seedlings were transplanted. The dead and very weak seedlings were replaced by the fresh and healthy ones soon after detection.

3.4.2 Fertilization

Except on farmers' farm, each plot received 100kg/ha of triple supper phosphate (TSP). On farmer practice plot, well decomposed cow dung and manure 1000kg ha^{-1} was applied. For nitrogen, urea fertilizer was applied in two splits, half at transplanting while the second half was applied 15 days after transplanting.

3.4.3 Cultural operations

17 days after transplanting, first weeding was done and the viability and vigour of the seedlings were carefully observed. Infestation of aphids and African ball worm were found in the vegetative stage and was controlled by systematic insecticide, carotenoid that was applied at 0.5liter ha^{-1}.

3.4.4 Soil moisture monitoring

Soil moisture was measured by tentiometer randomly at a depth of 20 cm before and after application of water every 3, 6, and 9 days from transplanting to harvesting. The equipment was finding from Jimma University.

3.4.6 Calculation of irrigation requirement

Irrigation requirement was calibrated according to the following equation Cropwat version 8.0 software and water was applied by using calibrated watering can to bring the water requirement of each interval days for the treatments The water requirement of cabbage is 469.1mm which is equal to 469.1liter per m^2 of land for all growing season. The area of each plot was 5.4m^2. The total water requirement of each plot was 2533.14liters for one plot. According to Cropwat version 8.0 software analysis the water needed for each day was 21.12litters. For 3 days' irrigation interval, the amount of water needed was 63.33litters, for six days' irrigation interval the amount of water needed was 126.66litters and for nine days' irrigation interval the amount of water needed is 189.99litters applied in each interval.

3.4.7 Water use efficiency

Water use efficiencies of cabbage were calculated according to Weiner *et al*., (2010) for evaluating the contribution of unit amount of water to crop yield. The computation was made using the following formula:

$$\text{Total water use efficiency (TWUE)} = \frac{\text{Total yield (kg/ha)}}{\text{Total water use (mm)}}$$

3.4.8 Harvest

Harvest was done plot wise after judging the compactness of cabbage head. The crops were harvested on February 2, 10, 22 and 25, 2015 and the total weights of the crops of individual plots were recorded.

3.5 Data collected

To evaluate effect of irrigation schedules and nitrogen fertilizer rate on cabbage growth and yield components four samples were taken from the two middle rows per plot. Based on four sampled plant head from each experimental unit, gross yield, marketable and unmarketable yield was weighed and converted in to t/ha. Plant whole fresh weight head diameter, height leaf number and harvest index were also collected from four samples per plot. Dry matter percentage was determined by taking slices from two heads per plot and dried at 78 ^{o}C for 48 hours until constant weight was attained (Semuli, 2005).

3.5.1 Growth parameters

Head height (HH) (cm)-cabbage head height (HH) was measured from selected plant sample from the central rows of the plot and their mean were recorded. The measurement was done with ruler from the tip head to down the collar at maturity and expressed in centimeter.

Head diameter (HD)(cm)-at harvest, randomly taken samples of cabbage heads from the central row was taken and the head diameter(HD) was measured at widest part using caliper (model LEG ilox-250m, USpatent) and would be expressed in centimeter.

Outer leaf number (OLN)-total numbers of fully developed outer leaves from each sample head were counted at time of harvesting.

Plant spread (PS) (cm) - plant spread (PS) was measured using ruler from east to west and north to south direction (Puru shottam, 2001). According to this the average plant spread was taken from the sample at time of harvesting.

3.5.2 Yield parameter

Whole plant fresh weight (WPFW) (kg/plant)-randomly selected sample plants were taken from the central rows of each plot and the whole plant parts was measured using beam balance (model WA310rev-B. Aeadam equipment).

Head weight (HW) (kg/plant)-at time of harvesting (91,101 and 109 day) randomly selected samples were taken from each treatment and their head weight was measured using analytical balance (Model WA310 rev-B dam equipment, made in china).

Unmarketable yield (UMY) (t/ha) - cabbage such as non-headed, split (brust), disease affected and under sized head (below 0.45kg was recorded as unmarketable yield NAARR (1986) and calculated based on t/ha.

Marketable yield (MY) (t/ha)-cabbage such as good headed, disease free and the size was >0.45kg was recorded as marketable yield and calculated based on (t/ha).

Total head yield (THY) (t/ha) - total number of heads and their weight were recorded as sum of marketable and unmarketable head yield and calculated based on t/ha.

Dry matter content (DM) (gram)-biomass of two randomly selected healthy plants was taken and the whole part was chopped. 200g sample was taken from the chopped weight (Semuli, 2005) and percentage dry matter content was calculated as the ratio between dried and fresh cabbage.

Harvest index (HI)-harvest index (HI) is the ratio of economic yield to biological yield. It is the characteristics of the movement of dry matter to the economic part of the plant. It was measured by taking the whole plant weight and only head weight separated and harvest index was taken as the ratio of head weight to total weight of the plant without including the root part.

3.5.3 Water use efficiency

The equation for estimating crop WUE (kg ha-1 mm-1) according to Kirda (2002) and Lovelli *et al*. (2007) is:

$$WUE = \frac{Y}{ETc}$$

Where Y is crop yield (kg ha-1) and ETc is actual evapo-transpiration (mm) which was regarded as crop evapo-transpiration (mm), in this study.

3.6 Determination of Crop and Irrigation Water Requirement of Cabbage

Crop water requirement of cabbage was determined using the Cropwat model based on the climatic data of the Jimma area, the crop grown (cabbage). Input data for the model was obtained from the National Meteorological Services Agency, Soil laboratory results and FAO publications. Twenty (20) years (1995 to 2015) meteorological data was used to estimate crop water requirement and the data were obtained from Jimma National Meteorological Station (Table 4). Calculations of water and irrigation requirements utilize inputs of climate, crop and soil data, as well as method of irrigation and rainfall data. Reference evapo-transpiration was calculated from temperature, humidity, sunshine and wind speed data, according to the FAO Penman-Monteith method (Allen *et al*., 1998).

Table 4 Climate data and reference evapo-transpiration at Jimma (1995 to 2014)

Month	Rainfall(mm)	Maximum Temperature(^{0}c)	Minimum Temperature(^{0}c)	Relative humidity (%)	Wind speed (m s^{-1})	Sun shine (h)	ET_O (mm day-1)
January	35.89	31.48	3.33	50.0	0.49	7.6	3.1
February	25.43	32.80	4.81	44.2	0.59	8.036	3.47
March	90.80	31.41	6.40	46.7	0.64	7.362	2.7
April	135.30	31.85	9.55	53.7	0.77	7.32	3.17
May	197.85	30.95	10.73	62.0	1.00	7.044	3.51
June	211.49	29.84	11.53	66.2	0.79	5.732	4.13
July	211.26	28.20	11.87	73.3	0.66	4	4.43
August	213.20	27.83	11.88	71.7	0.80	4.028	4.7
September	190.35	29.74	11.73	67.0	1.05	4.99	4.93
October	132.12	29.11	7.06	59.0	1.08	6.584	4.45
November	67.71	31.14	4.65	50.9	1.03	7.896	3.96
December	32.13	31.33	3.08	47.5	1.00	8.014	2.93
Total	1543.5						
Average		30.5	8.1	58	1	8.7	3.79

3.7 Soil Sampling and Analyses Before and After Planting

Soil samples were collected from Saka chekorsa woreda at 30cm depth by diagonal pattering sampling technique before planting. These samples were composited and prepared for determination of soil chemical and physical properties involving soil texture, organic matter, organic carbon, pH, and amount of phosphorus (P) and nitrogen (N). The soil samples were cleaned from root and other dusts, air dried thoroughly, mixed and ground pass a 2-mm size sieve before laboratory analysis.

The soil pH, OM%, % TN, AVP and texture were analyzed at Jimma university college of Agriculture and veterinary Medicine soil laboratory. Particle size distribution was determined by hydrometer method (differential settling within a water column) using particles less than 2 mm diameter (FAO, 2008). OM percentage was estimated multiplying OC by 1.72, pH by using pH meter; amounts of available phosphorus (P) was estimated by using as described by Bray II method extraction method as described by Bray and Kurtz (1945). Nitrogen by micro Kjeldhal digestion procedure by Bremmer (1996).

Field capacity and permanent wilting point of the soil were analyzed at Addis Ababa Water Works Design and Supervision Enterprise by using pressure plate apparatus at 0.33bar pressure for field capacity and 15bar pressure for permanent wilting point.

3.8 Plant Tissue Sampling and Analysis

Biomass of two randomly selected healthy plants were taken and the whole part was chopped.200g sample was taken from the chopped weight and oven dried at 70 ºC to a constant weight, ground to pass <1 mm sieve and stored for tissue analysis. Total N was quantitatively determined by a Kjeldahl procedure Bremer and Mulvarey (1982).

3.8.1 Determination of N in cabbage

Total N content was obtained after multiplying N concentration of the cabbage by total head yield.

$$\text{Apparent recovery efficiency (ARE) (\%)} = (\text{Nuf}–\text{Nu}/\text{Na}) \times 100$$

Where Nuf is the N uptake of the fertilized treatment (kg) and Nu is the N uptake of unfertilized treatment (kg) (Albrizio and Todorovic.*et al*, 2010).

3.9 Statistical Analysis

All data were examined for homogeneity of variance and normality. Then, those data which were found to have normal distributions were subjected to analysis of variance using proc GLM (general linear model) procedure of SAS 9.3 software (SAS Institute Inc.2009). The means was compared with least significant difference (LSD) at 5% significance level.

4. RESULTS AND DISCUSSION

4.1 Effects Irrigation Scheduling and Nitrogen Fertilizer Rate on the Growth of Cabbage Crop

4.1.1 Head diameter, head height, plant height and plant spread

Nitrogen fertilizer rate by irrigation schedule significantly ($P<0.001$, Appendix Table 2) affected head diameter, head height, plant height and plant spread parameter. The biggest head diameter 17.43cm was recorded at the treatments combination of 6 days' irrigation scheduling and 92kg ha^{-1} nitrogen fertilizer (Table 5). The smallest head diameter (9.37cm) was observed at the treatments combination of 3 days irrigation interval and zero N levels. The size of head of cabbage is genetically controlled but the size of the diameter of the head is directly related with yield performance. Optimum days of irrigation scheduling and higher nitrogen fertilizer rate favored better nutrient uptake by encouraging better physiological activities and leading better plant growth and bigger head formation.

The highest head height (19.67cm) was observed at the treatments combination of 6 days' irrigation interval and 92kg ha^{-1} of nitrogen fertilizer, the lowest (10.83cm) was at the treatments combination of 9 days' irrigation interval and without nitrogen fertilizer level (Table 5). This shows higher nitrogen fertilizer rate and optimum days of irrigation interval favored the head height of cabbage.

The interaction effect of irrigation scheduling and nitrogen fertilizer on plant height was highly significant (Table 5). The plants receiving highest dose of nitrogen and 6 days' irrigation scheduling had maximum height of 24.65cm which is statically similar with 69 kg ha^{-1} nitrogen fertilizer and 6 days' irrigation scheduling. Plants receiving no nitrogen fertilizer but irrigated at 9 days' irrigation interval had the lowest plant height (16.57cm). But, this value was statically similar with the height of the plants observed at treatment combination of 23kg ha^{-1} nitrogen and 9 days' irrigation interval.

Plant spread was significantly affected by interaction of nitrogen fertilizer rate and irrigation scheduling (Appendix Table 2). The narrowest plant spread (24.46cm) was observed from plants grown at 0kg/ha nitrogen fertilizer rate and 3 days of irrigation scheduling interval (Table 5). Widest plant spread at higher nitrogen rate 92kg/ha and at 6 days of irrigation interval (38.77cm), is due to higher nitrogen levels favor the growth of plants leading to larger leaf area that cover the wider space.

4.1.2 Outer leaf number

Outer leaf number of cabbage means number of outer leaf none headed. Nitrogen fertilizer significantly affected outer leaf number but irrigation scheduling and interaction of nitrogen fertilizer and irrigation scheduling had no any significant effect on outer leaf number. The highest outer leaf number was recorded (18.86) on the control of nitrogen fertilizer which was not significantly different from outer leaf number 18.66 which was recorded at 23 kg ha^{-1} of nitrogen fertilizer (Table 7). These results showed that number of non-wrapper leaves steadily decreased with increasing N concentration. Similar results were observed by Mustafa and Zohair (2013). According to these authors, application of N fertilizer, in successive amounts up to 350 kg ha^{-1}, to the growing cabbage plants, resulted in corresponding and significant decreases in the number of outer leaves.

Table 5 Interaction effects of nitrogen fertilizer rates and irrigation scheduling on growth parameter, water use efficiency of cabbage and nitrogen recovery

Treatments		HH (cm)	D (cm)	PS (cm)	PH (cm)	WUE(kg/ $ha^{-1}mm^{-1}$)	NRe (%)
Irrigation (days)	Nitrogen Fertilizer (kg ha^{-1})	Means					
3days	0	13.63	9.4	24.46	18.3	44.09	—
	23	14.07	11.69	27.23	19.17	55.8	81.8
	46	14.43	11.59	32.16	19.23	60.83	72.2
	69	14.53	12.61	33.65	20.02	103.86	65.45
	92	15.23	14.57	35.12	21.07	106.51	60.9
6 days	0	13.37	11.12	27.61	21.64	71.77	___
	23	14.55	12.69	29.03	20.6	74.21	44.58
	46	17.47	13.12	32.22	20.67	121.93	54.72
	69	18.53	14.22	33.89	23.87	133.51	56.95
	92	19.67	17.43	38.77	24.65	152.47	44.59
9days	0	10.83	11.45	27.43	16.57	48.82	___
	23	14.53	11.99	29.06	16.92	55.95	89.9
	46	14.9	12.72	30.66	19	89.08	89.4
	69	15.73	11.78	31.81	20.38	123.01	86.9
	92	16.83	13.53	34.11	21.15	131.64	87.8
Mean		15.22	12.65	31.15	20.21	14.07	56.69
CV%		1.45	2.29	2.39	2.46	14.06	6.9
LSD		0.3	0.4	1.25	0.85	1.87	6.52

HH=head height, D=diameter, PS= Plant spread, OLN=outer leaf number, PH =plant height, WUE= water use efficiency, NRe= nitrogen recovery

4.2 Effects Irrigation Scheduling and Nitrogen Fertilizer Rate on the Yield of Cabbage Crop

4.2.1 Dry matter, marketable and unmarketable yield, total head yield and whole fresh weight

Nitrogen fertilizer rate by irrigation schedule significantly ($P<0.001$, Appendix Table 1) affected dry matter, marketable yield, unmarketable yield, total head yield and whole fresh weight parameter.

Cabbage dry matter increased with increasing both nitrogen fertilizer and irrigation schedule. The highest dry matter (7.36%) was observed at the treatments combination of 92kg ha^{-1} nitrogen fertilizer rate and 9 days' irrigation scheduling (Table 6). The lowest dry matter (3.43%) was recorded at the treatment combination of 6 days' irrigation interval and 0kg ha^{-1} nitrogen fertilizer which is similar with Mohammed (2004). The author found the highest dry matter content at a treatment combination of 15-day irrigation interval with 240 kg ha^{-1} Nitrogen fertilizer rate and the lowest was recorded at 5 days irrigation interval and 0kg ha^{-1} nitrogen fertilizer rate. This shows that with increasing nitrogen fertilizer rate and long days' irrigation schedules; the crops can get more sun light than the other days of irrigation schedules this facilitate photosynthetic rate of the plant in relation to the fertilizer.

The highest marketable yield (64.5t/ha) was recorded at the treatment combination of 92 kg/ha nitrogen fertilizer level and 6 days' irrigation interval (Table 6). On the other hand, the lowest yield (20.09t/ha) was obtained from cabbage grown without nitrogen fertilizer and 6 days' interval which was stastically similar with 9 days irrigation interval without any nitrogen fertilizer application. Similar observation on cabbage marketable yield was also reported by Mohammed (2004). In this study, the highest marketable yield was recorded under 5 days' irrigation interval and 240 nitrogen fertilizer rate. This may be due to irrigation and nitrogen played a significant role in accelerating on vegetative growth of cabbage crops.

The lowest unmarketable yield (7t/ha) was recorded with the treatment combination of 92 kg/ha nitrogen fertilizer level and 6 days' irrigation scheduling whereas the highest unmarketable yield (30.91 t/ha) was recorded with the treatment combination of 6 days' irrigation scheduling without any nitrogen application (Table 6). This could be due to the synergic effect of irrigation scheduling and nitrogen fertilizer level missing of nitrogen application decrease the yield.

The highest total yield (71.52tone/ha) was recorded under the treatment combination 6 day's irrigation interval and 92 kg ha^1 nitrogen fertilizer which was significantly higher than all other treatments (Table 6, Fig.2). The lowest yield of 35.91 tone/ha was recorded under the treatment combination of 9 days' irrigation interval and 23 nitrogen fertilizer which was statically similar with the treatment combination of nine days' irrigation scheduling and 0 kg ha^{-1} nitrogen fertilizer. From this study, it has been found that application of both nitrogen and irrigation scheduling are indispensable increasing cabbage yield. Because there is higher uptake of nutrients (Bafna *et al*., 1993), and excellent soil-water-air relationship with higher oxygen concentration in the root zone (Gornat *et al*., 1973).

The interaction effect of irrigation interval and nitrogen level on whole fresh weight per plant was also highly significantly (Figure 2). The highest whole fresh weight 5.73kg was recorded at the three days irrigation schedules and an application of 92 kg/ha nitrogen fertilizer rate. The plants grown under the nine days irrigation interval without any fertilizer gave the lowest whole fresh weight (1.67kg/plant) suggesting that the plants were starved of N due to lack of adequate N uptake through irrigation water. On the other hand, the residual soil moisture that applied in three days' irrigation interval associated with the added nitrogen might be utilized efficiently to produce relatively higher whole fresh weight of cabbage as compared to the plots where no or minimum nitrogen was added. Similar results were also reported by Kadyampakeni (2013). They found that the yields of cabbage increase with increasing rates of applied fertilizer and with applied farm yard manure but optimum irrigation with a moderate increase in fertilizer rate gave the highest yield.

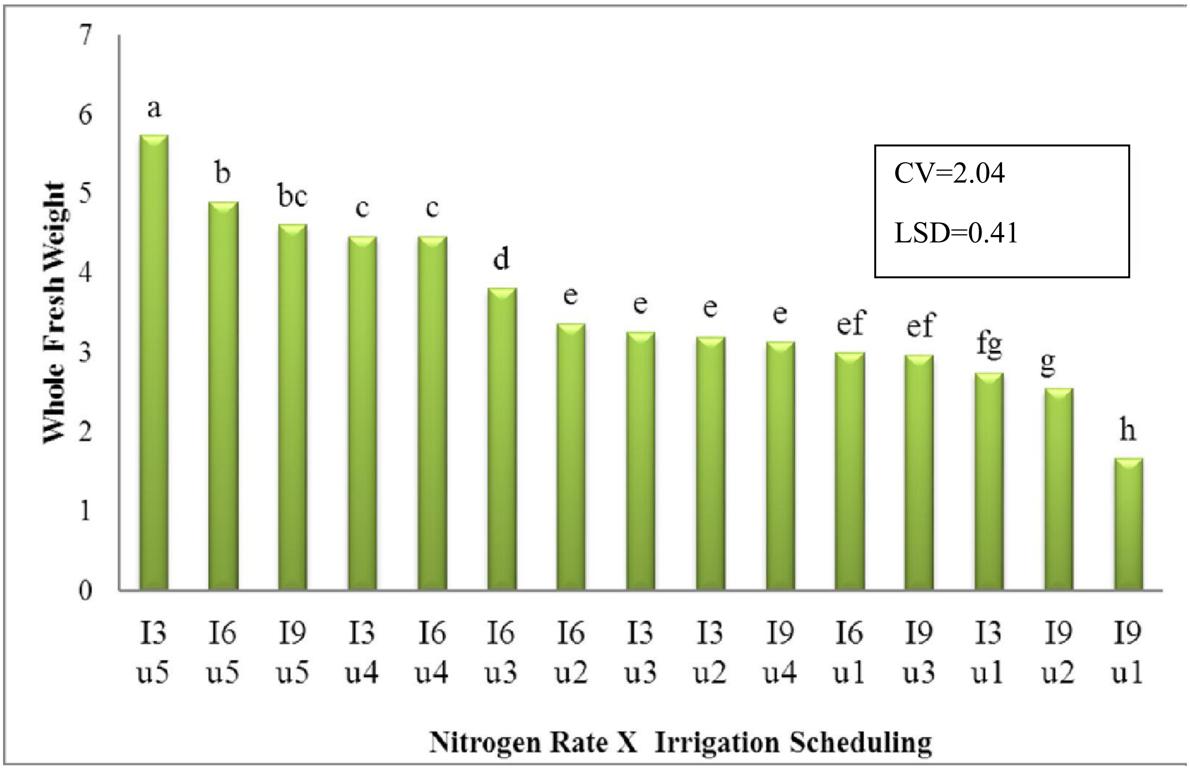

Figure 2 Interaction effects of nitrogen rate and irrigation scheduling on whole fresh weight

(I3U1=3 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I3U2=3 days irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I3U3= 3 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I3U4= 3 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer,
I3U5=3 days irrigation scheduling and 92 kg/ha nitrogen fertilizer,
I6U1=6 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I6U2= 6 days' irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I6U3= 6 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I6U4= 6 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer,
I6U5=6 days irrigation scheduling and 92 kg/ha nitrogen fertilizer,
I9U1=9 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I9U2= 9 days' irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I9U3= 9 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I9U4= 9 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer and
I9U5= 9 days' irrigation scheduling and 92 kg/ha nitrogen fertilizer)

4.2.2 Head weight

Cabbage head weight was significantly (*$P<0.05$*) affected by the interaction between nitrogen fertilizer and irrigation scheduling (Appendix Table 1). The highest head weight (3.28kg/plant) was obtained at the treatment combinations of 92 kg/ha nitrogen fertilizer rate and 6 days' irrigation scheduling (Fig. 3). But, the result was not statistically different from a treatment combination of 92 kg/ha nitrogen fertilizer and 3 days' irrigation intervals (3.23

kg/plant) (Table 6). The lowest head weight (1.12kg/plant) was found at the treatment combination of no nitrogen fertilizer and 9 days' irrigation interval. This was also not statistically significant with zero nitrogen fertilizer level and 3 days' irrigation interval as well as with 23 kg $ha^{-1}$and 3 days' irrigation interval. These results are similar with the results reported by Mohammed (2004). Since cabbage is heavy feeder for both nitrogen fertilizer rate and water, high amount of water and nitrogen fertilizer rate increase weight of head cabbage.

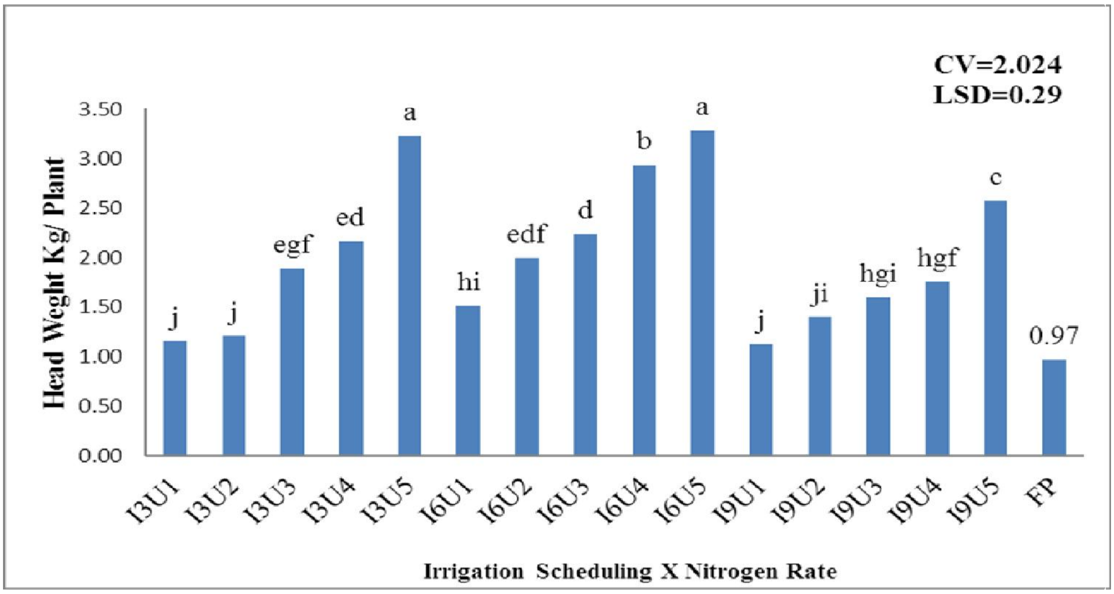

Figure 3. Effect of interaction between nitrogen fertilizer rate and irrigation scheduling on head weight of cabbage.

(I3U1=3 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I3U2=3 days irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I3U3= 3 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I3U4= 3 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer,
I3U5=3 days irrigation scheduling and 92 kg/ha nitrogen fertilizer,
I6U1=6 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I6U2= 6 days' irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I6U3= 6 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I6U4= 6 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer,
I6U5=6 days irrigation scheduling and 92 kg/ha nitrogen fertilizer,
I9U1=9 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I9U2= 9 days' irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I9U3= 9 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I9U4= 9 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer and
I9U5= 9 days' irrigation scheduling and 92 kg/ha nitrogen fertilizer)

4.2.3 Harvest index

Cabbage harvest index was highly significantly (*P<0.001*) affected by the main effect of nitrogen fertilizer rate and irrigation schedules. The interaction of nitrogen fertilizer level and irrigation schedules did not affect harvest index (Appendix Table 1).

The highest harvest index was recorded on the 92kg ha^{-1} (60%). The lowest was observed on the no nitrogen fertilizer (36.19%) (Table 7). This result is similar with the finding of Semuli (2005) who showed that the ratio of trimmed head to untrimmed head was higher at higher nitrogen level than lower nitrogen level. This shows that harvest index increased with increase in level of nitrogen fertilizer and nitrogen rate is clearly important for the allocation of assimilates to the harvestable part of cabbage crops. Sarke *et al*. (2002) also reported that higher harvest index was obtained from the higher rate of fertilizer.

Again, irrigation scheduling had highly significant effect on harvest index of cabbage crops. The highest harvest index (60.7%) was observed at 6 irrigation scheduling (Table 7). The lowest harvest index (48.58%) was recorded at 3 days' irrigation scheduling. implying both short interval and long interval of irrigation does not help to get good harvest index.

Table 6 Interaction effects of nitrogen fertilizer rates and irrigation scheduling on yield parameter of cabbage

Treatments		UMY(t/ha)	MY(t/ha)	TY(t/ha)	DRM(g)
Irrigation (days)	Urea (kg ha^{-1})	Means			
3days	0	17.28	21.73	39.02	4.09
	23	21.54	21.36	42.9	4.64
	46	19.6	26.64	46.25	4.72
	69	20.62	28.72	49.34	5.04
	92	12.05	38.19	50.25	5.52
6 days	0	30.91	20.09	51	3.43
	23	26.33	36.79	63.12	3.83
	46	12.53	44.04	56.56	4.31
	69	10.68	52.23	62.92	4.80
	92	7	64.5	71.52	5.02
9days	0	13.62	22.61	36.24	4.44
	23	12.51	23.41	35.91	5.11
	46	11.9	40.99	52.89	5.8
	69	11.2	46.17	57.37	6.64
	92	10.27	51.48	61.75	7.36
Mean		15.87	35.93	51.8	4.98
CV%		12.11	4.65	4.94	2.05
LSD		2.99	1.74	3.17	1.56

HW=head weight, UMY= unmarketable yield, MY= marketable yield, TY= total yield, WFW=whole fresh weight, DRM=dray matter, HI, harvest index.

4.3 Effects of Irrigation and Nitrogen on Nutrient Content of Cabbage

4.3.1 Total N content

The total nitrogen content of cabbage was affected by both irrigation scheduling and nitrogen fertilizer rate (Appendix table 4). Irrigation scheduling had significant influence on total nitrogen content of cabbage crops. Maximum nitrogen content of 3.33% was recorded under the six days of irrigation scheduling (Table 7). The lowest value 2.28% of nitrogen content found in nine days' irrigation scheduling which is statically similar with 3 days' irrigation schedules (2.31%). Better rooting system and plant growth under optimum days of irrigation interval might have enabled the plant to explore more nitrogen. Logically the plant nitrogen content increase significantly with each of nitrogen application, thus the resulting the higher nitrogen content 3.44% was under the highest nitrogen level (92kg). The minimum amounts of nitrogen content of 1.71% were found in plots where no nitrogen fertilizer was added. The interaction of nitrogen fertilizer level and irrigation schedules did not affect leaf nutrient concentrations. The findings were in line with the results reported by Padem and Alan (1995).

4.3.2 Nitrogen recovery

Nitrogen recovery of cabbage crops as influenced by irrigation scheduling and nitrogen fertilizer rate. The nitrogen recovery in cabbage is shown in table 6 and significantly influenced by interaction effect of nitrogen fertilizer rate and irrigation schedules ($P<0.001$, Appendix table 4).

The highest nitrogen recovery efficiency (89.9 %) was obtained at treatment combination of 23kg ha^{-1} nitrogen fertilizer rate and 9 days irrigation schedules which is statically similar with 46 kg ha^{-1} nitrogen fertilizer rate and 9 days irrigation schedules (89.4%), whereas the lowest nitrogen recovery (44.58 %) was recorded at treatment combination of 23kg ha^{-1} nitrogen fertilizer rate and 6 days irrigation schedules which is statically similar with 92kg ha^{-1} nitrogen fertilizer rate and 6 days irrigation schedules(44.59%). This shows that the quantity of nitrogen recovered in the cabbage heads was small relative to the quantity of N applied as fertilizer with optimum days of irrigation scheduling.

Table 5 Effect of irrigation scheduling and nitrogen fertilizer on total nitrogen rate, outer leaf number and harvest index parameter of cabbage

Treatments	Total nitrogen (%)	Outer leaf number	Harvest index
Nitrogen fertilizer rate (kg/ha)			
0	1.71	18.86	50.32
23	2.29	18.66	53.96
46	2.66	18.4	56.93
69	3.09	18.21	56.87
92	3.44	17.93	60.17
LSD (5%)	0.19	0.67	4.35
CV (%)	2.05	2.04	4.63
Irrigation scheduling			
3 days	2.31	18.75	48.58
6 days	3.33	18.57	60.7
9 days	2.28	18.66	53.02
LSD (5%)	0.15	0.5	3.38
CV (%)	2.04	2.04	4.3

Means followed by different letters per column differ significantly ($P < 0.05$) as established by LSD test.

4.4 Water Use Efficiency

The interaction effect of nitrogen fertilizer rate and irrigation scheduling significantly (P<0.05) affected water use efficiency of cabbage (Appendix Table 4). The highest water use efficiency 152.47kg $ha^{-1}mm^{-1}$ was recorded at the 6 days' irrigation scheduling and 92kg ha^{-1}nitrogen fertilizer (Table 5). The smallest water use efficiency (44.09kg $ha^{-1}mm^{-1}$) was at irrigation interval of 3 days and control of nitrogen fertilizer which was statically similar with 9 days' irrigation scheduling and control nitrogen fertilizer rate. The higher water use efficiency might be due to the lower rate of water loss through evaporation from soil surface. Michael (1978) also noted that nutrient and irrigation management practices can increase WUE by increasing crop yield. Similar results were supported by Khaled (2006) who reported that the highest WUE of Canola (*Brassica napus* L.) value was observed with the irrigation interval of 14 days, particularly in case of application the highest N rate (180 kg N ha^{-1}). Lower WUE with increasing irrigation interval more than 14 days (21 and 28 days) could be due to the decrease in yield with increasing the drought period.

4.5 Mean comparison of Farmer Practice with Recommended Treatments

To compare farmer practice with recommended which is 6 days' irrigation interval 92kg ha^{-1} nitrogen fertilizer rate by using paired t-test SAS software shown in the table 8. Both Farmer practice and the recommended result shows statically different. The means of head height, head diameter, plant spread, outer leaf number, whole fresh weight and head weight, 3.92, 2.57, 855.8, 3.09, 2.49 and 2.13 respectively. On average, the scores from farmer practice were lower than these results. On the other way comparing farmer practice with three days' irrigation scheduling with 92kg/ha nitrogen fertilizer and nine days irrigation scheduling with 92kg/ha nitrogen fertilizer the farmer practice is lower by 75.67 and 70.78 means. This was because application of fertilizer and water optimization was not the norm in farmers practice and thus, neither environmentally nor economically feasible.

Table 6 Mean Comparison of farmer practice with 6 day irrigation scheduling and 92kg/nitrogen fertilizer rate

Parameter	**Means difference**	**t- value**	**Pr >|t|**
Head height (cm)	-3.92	-65.18	0.0002
Diameter (cm)	-2.57	-7.39	0.017
Plant spread(cm^2)	-855.8	-15.88	0.007
Outer leaf number(no)	-3.09	-5.53	0.0312
Whole fresh weight(kg)	-2.49	-7.49	0.0123
Head weight(kg)	-2.13	-47.11	0.005

4.6 Nitrogen after Harvest in the Soil

The amount of nitrogen left in the soil after harvest was very highly significantly ($P<0.001$) affected by main effects nitrogen fertilizer level and irrigation scheduling. Combined effect of nitrogen fertilizer level and irrigation scheduling also affected amount of nitrogen left in the soil (Table 9). The highest amount of nitrogen (0.45%) left in the soil was recorded at higher nitrogen fertilizer level (92kg/ha) and nine days' irrigation interval whereas the lowest

(0.31%) was recorded at lower or zero level of nitrogen fertilizer and nine days' irrigation scheduling (Table 9) which is statically similar with 6-day irrigation interval and control nitrogen fertilizer. Increasing nitrogen rate from 0 to 92 kg/ha increased soil total nitrogen by 100%. The nitrogen left in the soil at no nitrogen fertilizer rate and 23 kg/ha were lower when compared with pre-planting nitrogen (0.37%) but increases in the case of 46, 69 and 92kg/ha of nitrogen rate. Increasing nitrogen and plants inability to uptake as result of limited soil water has probably increased post-harvest total soil nitrogen. The current finding agrees with the report of Frezer (2007) that reported increasing nitrogen level increased post-harvest soil total nitrogen. If water is not optimized for the nutrient to be taken up, total nitrogen builds up in the soil. Salo (1999) also reported that nitrogen after harvest tends to increase with increasing amount of fertilizer applied. This means a loss if N and water application are not synchronized and nutrient is taken up there could be potential danger for environment or it might be washed to ground water.

Table 7 Laboratory soil nitrogen analysis

Irrigation (days)	Nitrogen Fertilizer rate (kg ha^{-1})	Percentage of nitrogen left in the soil after harvest
3	0	0.35
3	23	0.36
3	46	0.37
3	69	0.37
3	92	0.38
6	0	0.31
6	23	0.32
6	46	0.34
6	69	0.37
6	92	0.42
9	0	0.31
9	23	0.35
9	46	0.38
9	69	0.42
9	92	0.45
	Farm yard manure and cow dung with 7 days	0.36
LSD (5%)		0.03

5. SUMMARY AND CONCLUSION

Cabbage is a good source of vitamin K, vitamin C and dietary fiber. Contaminated cabbage has been linked to cases of food-borne illness in human. The productivity and availability of cabbage in the market is low as compared to winter season and is mostly needed as a fastening food. To get higher yield depends up on a proper consideration of optimum days of irrigation scheduling per unit area in which a given area there is supply of quantity of plants get given irrigation interval and amount of water suitable for the plant and fertilizer. This experiment was done to see effect of irrigation schedules and optimum water application on growth and production of cabbage crop. The study was aimed to identify optimum amount of water and nitrogen rate for cabbage production for the study.

The experiment was laid out in 3 x 5 factorial arrangement in randomized complete black design with three replications comprising three levels of irrigation scheduling (3 days, 6 days and 9 days) and five levels of nitrogen fertilizer (0, 23, 46, 69 and 92kg/ha) using Copenhagen market cabbage variety.

Dry matter, marketable yield, unmarketable yield, total head yield and whole fresh weight were affected by irrigation scheduling and nitrogen fertilizer rate. Increased nitrogen fertilizer from 0 to 92 kg/ha increased the above parameters. Higher cabbage dry matter percentage (7.36%) was recorded at 92 nitrogen fertilizer rate levels and nine days' irrigation scheduling. Higher marketable yield (64.5 t/ha), higher total yield (71.52 t/ha) and bigger total plant fresh weight (5.73kg/plant), were recorded at higher nitrogen fertilizer rate of 6 days' irrigation interval and 92kg ha^{-1} nitrogen rate.

The highest head weight (3.28kg/plant) was obtained at the combination of higher nitrogen fertilizer rate of 92 kg/ha and 6 days' irrigation scheduling. Harvest index was also affected by nitrogen fertilizer rate and irrigation scheduling. Higher harvest index (60%) was recorded at higher nitrogen fertilizer level (92kg/ha) and 60.47% harvest index was recorded at 6-day irrigation scheduling.

Nitrogen fertilizer rate by irrigation schedule significantly affected head diameter, head height, plant height and plant spread parameter. Plant spread, head height and diameter, were found to be affected significantly by the main effects. Wider head diameter (17.43cm), longer head height (19.67cm), maximum height of 24.65cm and wider plant spread (38.77cm) were recorded at higher nitrogen fertilizer rate (92 kg/ha) and 6 days' irrigation scheduling.

The result obtained from the experimentation showed that irrigation scheduling at six days and nitrogen fertilizer at 92 kg ha^{-1} were optimum amount for cabbage growth and production and can be recommended for the study area. This optimum treatment combination resulted in higher nitrogen content (3.35%), higher nitrogen recovery (89.9 %) and higher water use efficiency (152.47kg $ha^{-1}mm^{-1}$) for cabbage crop. Comparing of farmer practice with 6 days' irrigation scheduling and 92kg of nitrogen fertilizer and with 3days and 9days irrigation scheduling by 92 kg ha^{-1} nitrogen fertilizer all the above variables were greater in this optimum treatment combination than in farmers' practical management.

Since cabbage crop responded positively to optimum irrigation interval and increasing nitrogen fertilizer rate. The farmer of the studied area should be used 6 days' irrigation scheduling and 92 kg/ha nitrogen fertilizer rate for their increment of cabbage yield, the experiment was worked by water cane to measure the amount of water but the farmer uses by their own suitable irrigation method for application of water. The experiment was conducted at one location for only one season; further investigations may be needed to be carried out at different seasons of the year, location, soil type, cabbage varieties and different farmer practice to come up with precise and comprehensive recommendation. And, further research need to combine another nitrogen fertilizer rate and with combining effect nutrients with phosphorous, potassium and other nutrients with this irrigation interval.

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7. APPENDICES

Appendix Table 1. Mean Square of Yield Parameter

Source of variations	DF	HW	UMY	MY	TY	WFW	DM	HI
		Mean Square						
Replication	2	0.07ns	0.13ns	6.67ns	6.23ns	0.23ns	1.01ns	34.86ns
Irrigation scheduling	2	1.93**	179.32**	995.82**	997.22**	4.15**	9.87**	587.11**
Nitrogen fertilizer	4	4.26**	184.6**	1277.72**	506**	8.97**	5.46**	114.52*
Irrigation scheduling with Nitrogen fertilizer	8	0.15*	96.51**	111.4**	87.14**	0.34**	0.38 *	174.69ns
Error	28	0.03**	3.69**	2.79**	6.54**	0.05**	0.18**	30.88*
Total	44							
Mean		2	15.87	35.93	51.8	3.59	4.98	55.65
CV%		8.37	12.11	4.65	4.94	6.07	5.83	9.99
LSD		0.22	0.08	1.74	0.62	2.31	0.44	4.63

*= significant, ** = highly significant, ns = non-significant, DF = degree of freedom, HW= head weight, UMY=unmarketable yield, MY=marketable yield, TY=total yield, WFW=whole fresh weight, DM=dry matter, HI=harvest index.

Appendix Table 2. Mean Square of Growth Parameter

Source of variation	DF	HH	HD	PS	OLN	PH
Replication	2	0.04ns	0.004ns	114.84ns	1.38ns	0.48ns
Irrigation scheduling	2	25.28**	2.86**	95121.97**	0.4ns	50.31**
Nitrogen fertilizer	4	28.9**	24.21**	180466.27**	1.4*	21.88**
Irrigation scheduling with Nitrogen fertilizer	8	4.47**	5.1**	7502.44**	0.8ns	2.13**
Error	28	0.05**	0.08**	208.67**	0.42*	0.24**
Total	44					
Mean		15.22	12.65	1132.88	18.4	20.21
CV%		1.45	2.29	1.27	3.52	2.46
LSD		0.3	0.4	23.72	1.16	0.85

*= significant, ** = highly significant, ns = non-significant, DF = degree of freedom, PS=plant spread, OLN=leaf number, OLA=leaf area, HH=head height, HD=head diameter, PH= plant height.

Appendix Table 4. Mean Square of Nitrogen Recovery and Water Use Efficiency

Source of variation	DF	Total nitrogen	Nitrogen recovery	Water use efficiency
Replication	2	0.09ns	0.27ns	1556ns
Irrigation scheduling	3	5.38**	724.57**	5051**
Nitrogen fertilizer	5	4.12**	11339.3**	10191**
Irrigation scheduling with Nitrogen fertilizer	7	0.057ns	89.37**	253.66**
Error	28	0.04**	15.3**	16.42**
Total	44			
Mean		2.64	1.51	91.57
CV%		7.08	13.19	14.06
LSD		0.15	0.34	1.87

*= significant, ** = highly significant, ns = non-significant, DF = degree of freedom

Appendix Plat 5. Partial View of the Experimental Layout and Site