GROWTH AND YIELD RESPONSE OF HOT PEPPER (*Capsicum annuum* L.) TO BLENDED FERTILIZER RATES AND CULTIVARS IN RAYA AZEBO, NORTHERN ETHIOPIA

M.Sc. THESIS

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Wakuma Biratu Dose

M.Sc. Thesis

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I have incorporated the suggestion and modifications given during the internal thesis defense and got the approval of my advisers. Hence, I hereby kindly request the Department to allow me to submit my thesis for external defense.

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Decision/suggestion of Department Graduate Council (DGC)

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Chairperson, DGC	Signature	Date
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Chairperson, CGS	Signature	Date

DEDICATION

I dedicate this thesis work to Derartu Cheneka, my family and Garedow Jaleta who always encourage me to do something and are happier to see me successful throughout my work.

STATEMENT OF THE AUTHOR

I, Wakuma Biratu, declare that this thesis is my own work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at the Jimma University College of Agriculture and Veterinary Medicine. I solemnly declare that this thesis work is not submitted to any other institution for the fulfillment of any academic degree, diploma or certificate.

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Place: Jimma University
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BIOGRAPHICAL SCKETCH

The author, Wakuma Biratu, was born from his Mother Tefani Sori and his Father Biratu Dose in Oromia National Regional state of Ethiopia West Shewa Zone Bako Tibe Woreda Guto Meti Kebele on February 15, 1991. He attended his elementary school at Guto Adulan in Bako Tibe woreda from 1997 to 2004. Then, he attended secondary and preparatory school at Bako town from 2005 to 2008. He joined Ambo University in 2009 and graduated with Bachelor of Science in Horticulture in June 2012.

After graduation, he was employed by Euro flora PLC and worked for seven months in 2012/13, then after he was employed by office of Small and Micro Enterprise in West Shewa Zone Jibat Woreda in 2013, where he worked for one year. In 2014, he was employed by EIAR Mehoni Agricultural Research Center as junior researcher in the Fruit, Vegetable and Root and Tuber crops research team.

He joined Jimma University College of Agriculture and Veterinary Medicine in 2016/17 Academic year to pursue his postgraduate study leading to M.Sc. in Horticulture.

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LIST OF ACRONYMS AND ABBREVIATIONS

ATA	Agricultural Transformation Agency
CSA	Central Statistical Authority
DAP	Diammonium phosphate
EIAR	Ethiopian Institute of Agricultural Research
FTC	Farmer training Center
GTP	Growth and Transformation Plan
IAA	Indoleacetic acid
MhARC	Mehoni Agricultural Research Center
OC	Organic Carbon
CP	Office Cherifien des Phosphates
LAI	Leaf Area Index
TLA	Total leaf area

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Growth and Yield response of Hot Pepper *(Capsicum annuum* L.*)* to Blended Fertilizer Rates and Cultivars in Raya Azebo, Northern Ethiopia

ABSTRACT

*Hot pepper (Capsicum annum L.) is the most widely cultivated and economically important crop. However, its production and productivity are constrained by different factors among which variety and fertilizer level are the major ones. Thus, field experiment was conducted at Mehoni Agricultural Research Center using two hot pepper cultivars (Melka Shote and Melka Awaze) and five blended fertilizer rates (NPSZn) + urea and one without fertilizer (control) to determine the growth and yield response of hot pepper under Raya Azebo condition. A 2*6 factorial experiment was laid in RCBD with three replications. Data on plant height, canopy diameter, total leaf area, leaf area index, number of branches plant*$^{-1}$*, above ground dry biomass, days to 50% flowering, days to first harvest, number of pods plant*$^{-1}$*, marketable, unmarketable, and total dry pod yield, pod size and thousand seed weight were taken and analyzed using SAS version 9.3. ANOVA revealed that plant height, days to first harvest, total leaf area, leaf area index, days to 50% flowering, number of pods plant*$^{-1}$*, marketable, unmarketable and total dry pod yield and pod length were significantly (*$p<0.05$*) affected by the interaction effect of cultivars and NPSZn + urea rates. Number of primary and secondary branches were highly significantly (*$p<0.01$*) affected by the main effect of cultivars and NPSZn + urea, respectively. The tallest plant height (61.27 cm) and the widest canopy diameter (59.63 cm) were recorded from the combination of Melka Awaze with 104NPSZn + 168 urea kg ha*$^{-1}$*. The maximum leaf area index (5.57) and total leaf area (9184.4 cm*^{2}*) were observed when Melka Shote was combined with 104 NPSZn + 168 urea kg ha*$^{-1}$*. The highest above ground total dry biomass (121.13 g) was recorded at the combination of Melka Shote with 84.5 NPSZn + urea kg ha*$^{-1}$*. The highest (11.71) number of primary branches were recorded from Melka Shote cultivar. The maximum number of secondary branches (12.10) plant*$^{-1}$* and thousand seed weight (8.52 g) was obtained at the rate of 84.5 NPSZn + 136.5 urea kg ha*$^{-1}$*. The interaction of Melka Awaze cultivar with 104 NPSZn + 168 urea kg ha*$^{-1}$* and 84.5 NPSZn + 136.5 urea kg ha*$^{-1}$* extended days to 50% flowering (both 99.33 days). The combination of Melka Shote with the control delayed days to first harvest (177.33 days). The highest average number of pods plant*$^{-1}$* (43.47), marketable dry pod yield (2.29 t ha*$^{-1}$*) and total dry pod yield ha*$^{-1}$* (2.44 t ha*$^{-1}$*) were recorded when Melka Shote interacted with 84.5 NPSZn +136.5 urea kg ha*$^{-1}$*. The longest pod length (10.99 cm) was noted at the combination of Melka Awaze with 65 NPSZn + 105 urea kg ha*$^{-1}$*. The application of 84.5 NPSZn + 136.5 urea kg ha*$^{-1}$* to Melka Shote cultivar was the most profitable. In general, the growth, phenological and yield of Melka Shote and Melka Awaze cultivars significantly influenced by NPSZn + urea rates whereby the highest marketable dry pod yield (2.29 t ha*$^{-1}$*) and the most economically profitable yield was recorded when Melka Shote combined with 84.5 NPSZn +136.5 urea kg ha*$^{-1}$*. So, the combination of Melka Shote cultivar with 84.5 NPSZn +136.5 urea kg ha*$^{-1}$* can be recommended for the growers around the study area and other areas having similar agroecology. Since, this result is based on one season data, it is suggested to repeat the study to come up with sound recommendation suitable for the area.*

Key words: *Cultivars, Interaction, Melka Awaze, Melka Shote, Urea*

1. INTRODUCTION

Pepper (*Capsicum annuum* L.) belongs to nightshade (Solanaceae) family. The *Capsicum* consists of approximately 30 species, of which *Capsicum annuum* L., *C. frutescens* Mill., *C. baccatum* L., *C. chinense Jacq. and C. pubescens Ruiz* and *Pavon* are domesticated and currently cultivated species in the world (Moscone *et al*., 2006; Aguilar-Melendez *et al*., 2009). Of the five domesticated species with a large number of mild and pungent types of cultivar distributed in various parts of the world, Capsicum *annuum L.* is the most widely cultivated and economically important. It includes sweet pepper as well as hot peppers, and those dried for chili powder and paprika (Stomme and Albrecht, 2012; Lin *et al*., 2013). *Capsicum spp.* is the most common crop in the countries of the tropics and subtropics with *Capsicum annuum* L. by far the most widespread species as spice and as a vegetable (Bostland and Votava, 2000; Berke, 2002).

Hot pepper dominates world spice trade; while, sweet pepper has become a popular vegetable and cash crop in the tropics for smallholders (Lin *et al.,* 2013). In many areas, pepper is grown predominantly as monocrop, and rotated with cereals or legumes, during the main rainy season. However, pockets of production in the dry season using irrigation also found, particularly in the rift valley of Ethiopia (Getahun and Habtie, 2017).

Peppers are widely grown in various parts of Ethiopia; small-scale farmers produce the largest proportion of hot pepper in the country (Getahun and Habtie, 2017). The fruits are consumed as fresh and dried, row material for the processing industries, important cash crop for farmers, and source of employment to urban and rural populations (Fekadu and Dandena, 2006). Hot pepper is a high value and important cash crop for smallholder farmers in developing countries which has potential for improving the livelihoods of thousands of smallholder farmers in Ethiopia (CSA, 2006; ICARDA, 2016; Getahun and Habtie, 2017).

Today, the crop has not only attained economical, but also traditional importance. It is one component of the daily diet of Ethiopian people. Peppers are important in the local dishes as green pod, fine powder from the dry fruits of hot pepper, grinded mature green fruits blended with other spices. The powder from dried ripe fruits of hot pepper is used as spice to flavor an Ethiopian stew in a daily traditional meal (Getahun and Habtie, 2017).

Despite enormous importance of pepper as vegetable, spice, medicine and ornamental, the production and productivity of hot pepper is low. Evidently, FAO, (2016) revealed that world dry chilies and peppers coved an area of 1.8 million ha with total production of 3.9 million tonnes. While, green chilies and peppers occupied total area of 1.9 million ha and total production from this harvested area is 34.5 million tonnes. In terms of productivity, dry chilies and peppers produced yield ha^{-1} of 2.2 tonnes and that of green chilies and peppers 17.8 tonnes ha^{-1}.

In case of Ethiopia, green and red pepper covers an area of 190,533.74 hectare which shares about 79.5% of the total area occupied by vegetable crops (239,609.76 hectares) at the national level. In terms of production, green and red peppers share 48.2% of vegetable production whereby 391,598.6 tonnes of both peppers produced at the national level with yield per hectare of 1.83 and 6.3 t ha^{-1} for red and green peppers respectively (CSA, 2017).

The average output ha^{-1} for green and red dry pod is low as compared to that of world average production pepper cultivars in Ethiopia particularly in Raya Valley. This could be due to one or more of the different productivities limiting factors including shortages of improved cultivars, inadequate seed production and promotion, poor extension works, susceptibility of released cultivars to diseases, poor agronomic practices (plant population, irrigation amount and frequencies, fertilizer type and levels) across location and seasons with corresponding cultivars (Fekadu and Dandena 2006; Shumeta, 2012; Getahun and Habtie, 2017).

However, in Raya Valley, only some research activities have been carried out such as adaptation trial on hot pepper (Gebremeskel *et al*., 2015), plant population (intra and inter row spacing) for a single season and at one location, DAP and urea rates (Teka, personal communication, 2017). Gebremeskel *et al*. (2015) have conducted an adaptation trial on four commercial hot pepper cultivars (Mareko Fana, Melka Shote, Melka Awaze and Melka Zala) and had observed a repeated failure of the Melka Zala cultivar to germinate. On the other hand, the highest, and significantly different marketable yield (353.43 q ha^{-1}) and the lowest (325.45 q ha^{-1}) were obtained from Melka Awaze and Mareko Fana cultivars. However, Melka Shote cultivar has a great acceptance by farmers due to the level of pungency, pod color and resistance to wilt disease and both Melka Shote and Melka Awaze cultivar was recommended for the farmers. Despite its larger pod size, Mareko Fana cultivar was found to be highly vulnerable to wilt diseases and gave lower yield, thus farmers are not interested to the cultivar from the feedback on demonstration site at Raya valley. Similarly, Sibhatu *et al. (*2016) found Melka Shote to be early maturing and gave the highest dry fruit weight, fruit length, plant height, and has shown relatively good performance. It also gave the highest marketable dry pod yield; indicating that Melka Shote cultivar had performed well and was recommended for the growers in the study area and other areas having similar agro-ecologies.

However, there are huge research gaps in all horticultural, cereals and other crops in terms of cultivar development, crop water requirement, planting time, plant population for different season and location, fertilizer level for each crop. Therefore, to help the producers achieve sustainable production, increase their income and improve their livelihood, it is very important to promote best adaptable and high yielding cultivars along with optimum rate of blended fertilizers. Particularly in Raya valley, hot pepper is a major spice and vegetable crop produced by the majority of farmers. It is one among the vegetable crops on which there was no necessary agronomic practices such as plant population ha^{-1}, amount and frequency of irrigation and blended fertilizer rate studies have not been undertaken.

Thus, the present work is initiated to study the effect of different rates of blended fertilizer (NPSZn) + urea on growth and yield of already recommended hot pepper cultivars. NPSZn was recommended for Raya Azebo district with percentage composition of 17.7N-35.3P_2O_5+6.5S+2.5Zn (ATA 2015). It is now recognized that the use of blended fertilizer is much more preferable as compared to that of urea and DAP in that balanced application of N, P, K, S, Zn, Fe or other micronutrients is essential to increase crop yields and to optimize nutrient, water and energy utilization. Additionally, balanced nutrient application can substantially reduce accumulation and leaching of nitrate-N in the soil profile, minimizing the potential for soil and ground water contamination (Malhi and Brandt, 2014).

ATA (2015) and Gerstenmier (2015) reported that most fertilizers available in African markets are limited to DAP (Diammonium phosphate) and urea containing only a few major nutrients (primarily nitrogen and phosphorus). They also reported these fertilizers lacks secondary macro and micronutrients that are increasingly recognized as deficient in different soil groups and reducing the yield and quality of crops. For the past four to five decades, using of DAP and urea fertilizers which contains N and P only as blanket recommendation was common in Ethiopia regardless of differences in soil types and agro-ecologies (Agegnehu and Tsigie, 2004; Kassahun, 2015).

Gerstenmier (2015) reported that continuous intensive cropping of hot pepper and other crops with inadequate fertilizer use has resulted in depletion of the soil's macro and micronutrients which in turn reduces yield. Recently, this situation is changing and the use of blended fertilizer which is known to be more closely matching with the specific needs of soils in Africa, including Ethiopia is coming up. From the point of importance, N and P have become increasingly recognized around the world that their sole application is not always sufficient to provide balanced nutrition for optimal crop yields and quality. While application of secondary and micronutrient (such as Zn, B, S, and Fe and other micronutrients) have been made possible, thanks to the availability of the blended fertilizers (Brar and Ludhiana, 2006).

Thus, this work was initiated with the objectives to

- ✓ Determine the response of two hot pepper cultivars to different levels of blended (NPSZn) fertilizers for growth and yield,
- ✓ Determine the optimum rate of NPSZn for production selected hot pepper cultivars
- ✓ Assess a possible interaction effect of cultivars and rate of blended fertilizer on growth and yield of hot pepper.

2. LITERATURE REVIEW

2.1. Overview of Hot Pepper

Hot pepper (*Capsicum annuum*) is one of Solanaceae family originated and diversified in south-central and South America. The *Capsicum annuum* L. complex, which includes three closely related species, *C. annuum* L.*,* *C. frutescens* and *C. chinenses* are the most widely grown in the America and worldwide. *C. annuum* L. had been domesticated in the highlands of Mexico and most of the hot peppers in Africa and Asia and various cultivars of sweet peppers grown in temperate countries. *C. frutescens* and *C. chinenses* are cultivated in Africa and Asia as spice crop, as intact fruits or for their oleoresin content. *C. baccatum* and *C. pubescens* are predominantly confined to Latin America Pickersgill (1997) as cited by Getahun and Habtie (2017). There is no exact information on when pepper was introduced to Ethiopia; however, it is cultivated in many areas of the country for home consumption and export (CSA, 2006). The main producing areas in the country are the central (Eastern and Southern Shoa), Western, North Western and the Northern part (ICARDA, 2016).

Pepper is a dicotyledonous woody perennial and a small shrub grown as annuals (Bosland and Votava, 2000). It has different growth habit (erect, semi erect and prostrate/spreading); usually 46-61 cm tall, but they can grow taller. The fruit follows a single flower (solitary) growing in the angle between the leaf and the stem (Albert, 2010; Stomme and Albrecht, 2012). Cultivated peppers are all members of the world *Capsicum* species. In Ethiopia, different pepper types such as non-pungent (bell/sweet) and pungent (chili and hot pepper) are produced with hot pepper is the dominant one (ICARDA, 2016).

2.2. Importance of Hot Pepper

In many countries of the world, pepper is a cash crop with high domestic and export value (Getahun and Habtie, 2017). Pepper is an important and popular pungent cash crop for smallholder farmers in developing countries such as Ethiopia, Nigeria, Ghana, China, India, Pakistan, Bhutan, Indonesia, Cambodia, and Thailand (Lin *et al.*, 2013). They were probably first used as medicinal plants to treat asthma, cough sand sore throats (Bosland and Votava, 2012). According to Lin *et al*. (2013), uses of pepper are generally grouped into five broad market categories: i) fresh market (green, red, multi-color whole fruits), ii) fresh processing (sauce, paste, canning, pickling), iii) dried spice (whole fruits and powder), iv) industrial extracts (paprika/ oleoresin, capsaicinoids and carotenoids) and v) ornamental (plants and fruits). *Capsicum* consumption is increasing and may represent an important source of vitamins for world populations. The antioxidant vitamins C, E and provitamin A as well as good sources of carotenoids and xanthophylls are present in high concentrations in various pepper types (Bosland and Votava, 2012).

Pepper is a very important crop not only in the fresh form but also row material for the processing industries, important cash crop to farmers, and a source of employment to urban and rural populations for spice extraction since it has a lot of oleoresin for dying of food items. Ethiopia is among few developing countries that have been producing paprika and *Capsicum* oleoresins for export market (Fekadu and Dandena, 2006).

2.3. Agro- ecological Requirements for Hot Pepper

Pepper is a warm-season crop that requires similar growing conditions with those needed by tomatoes and eggplants. However, it can also be extensively grown under various environmental and edaphic conditions. In suitable climatic conditions, some *Capsicum* spp. can live for a decade or more in the tropics (Bosland and Votava, 2000). There are three agro-ecological factors (rainfall, soil condition and temperature) affecting production of pepper (Ashilenje, 2013).

2.3.1. Rainfall and altitude

Hot peppers can grow in a wide range of altitudes (lowland, midland/midaltitude and upland) in which lowland areas are more suitable for optimum production of the crop (Ashilenje, 2013). In general, it grows under a wider range of altitudes ranging from 1000 – 2100 masl (MoARD, 2009). It requires mean annual rainfall between 600-1250 mm and areas which are free of water logging and flooding (Anonyms, 2016). Areas that experience in sufficient rainfall patterns need irrigation to supplement the rainfall (Ashilenje, 2013).

2.3.2. Soil and air temperature

Temperature (both air and soil) is one of the most important factors determining the growth, development and performance of pepper. Pepper requires very stable temperature ranges with minimums and maximums not being too far apart. Peppers do best with a long, frost-free season; the plant ceases growing at air temperature below 10° - 12°C, while at 6°C or less, the leaves can die and flower abortion will start. An increasing temperature of the air over 35°C will also result similar effect. Optimum air temperatures during day time ranges from 25 - 28°C, while at the night time it ranges from 16 - 18°C (Bosland and Votava, 2012; Lin *et al.*, 2013; Starke ayres, 2014). While the optimal soil temperature for peppers is 18°C (Albert, 2010). In general, temperature requirement varies with stage of development (Table 1).

Table 1 . Required temperature ranges per development stage for sweet and hot pepper

Developmental stage	temperatures (°C)		
	Minimum	Optimum	Maximum
Germination	23	26 – 28	30
Vegetative growth	21	23 – 25	28
Fruit set (night)	15	17 – 18	20
Fruit set (day)	20	23 – 25	28
Colouring	18	20 – 24	30
Cold damage		Under 6	
Frost damage		Under 1	
Terminal damage		-2	

Source: Starke Ayres (2014)

2.3.3. Soil characteristics

Peppers are grown under a wide range of soil conditions (Anonyms, 2016). The quality and quantity of pepper pods and growth of the plants are greatly influenced by the fertility and nutrient levels of the soil (Albert, 2010). Pepper plants do not perform well in clay and infertile soil. Thus, pH of 5.5-6.8 (Anonyms, 2016), high level of soil fertility and well drained sandy to loam soils are ideal for the nutrient uptake, healthy growth and production (Albert, 2010; Starke Ayres, 2014).

2.4. Status of Pepper Production in the World

Peppers are grown in most countries of the world. Annual production for both spice and vegetable use has been increasing over the years. The top 20 pepper-producing countries in the world produced 16,735,240 tonnes of fresh/green (pungent or non-pungent) peppers. In Africa, dry chilies and peppers occupied an area of 306233 hectare and gave yield ha^{-1} of 2.7 tonnes with total production of 810568 tonnes from the harvested area (CSA, 2012). FAO (2016) reported that world dry chilies and peppers coved an area of 1.8 million ha with total production of 3.9 million tonnes. While, green chilies and peppers occupied total area of 1.9 million ha and total production from this harvested area is 34.5 million tonnes. In terms of productivity, dry chilies and peppers produced yield ha^{-1} of 2.2 tonnes and that of green chilies and peppers 17.8 tonnes ha^{-1}.

2.5. Status of Pepper Production in Ethiopia

CSA (2017) reported that area coverage by vegetable was 239,609.76 hectares at national level; of this, the lion share (190,533.74 hectare) which account for about 79.5% was held by both red and green peppers with yield ha^{-1} of 1.83 and 6.3 t ha^{-1} for red and green peppers respectively. According to CSA (2017) the production of both red and green peppers was 391598.6 tonnes, where vegetables accounted totally 812624.87 tonnes; thus, green and red peppers share 48.2% in terms of production. Generally, Oromia, Amhara, SNNP, Benishangul, and Tigray National Regional States are the leading in terms of total production in descending order of both green and red pepper with 176,791, 128,568, 73,826, 6948 and 5437 tonnes, respectively (CSA, 2017). Whereas improved hot pepper cultivars, released by the national research institute, have been giving yield ranging from 1.8-2.5 t ha^{-1} dried and 15 - 20 t ha^{-1} green pepper at research stations (Simon and Tesfaye, 2014; Gebremeskel *et al*., 2015).

2.6. Production Potential and Constraints in Ethiopia

Hussen *et al*. (2013) reported increasing production of the hot pepper, which in turn has a great role to strengthen the growing vegetable industries in the country. The authors also reported that the production and productivity of the crop in the country is influenced by different factors among which improper plant spacing is one of the reasons of the low productivity of this crop. The major factors that limit vegetable crops production are shortage of cultivars and agronomic practice, poor quality seed, poor irrigation systems, lack of information on soil fertility, diseases, high postharvest loss and poor marketing system (Lemma, 2002).

However, the Government of Ethiopia has designed an ambitious Growth and Transformation Plan (GTP) that foresees Ethiopia in the bracket of a middle-income country by 2020. Owing to the fact that Ethiopia has vast potential for agricultural production, the GTP primarily focuses on boosting agricultural production (Tefera and Tefera, 2013).

Ethiopia is endowed with abundant agricultural resources with diverse physical features that allow the country to be divided into 18 major agro-ecological zones and 62 sub-zones. There are different agricultural investment opportunities in the cultivation of horticultural products. These includes market opportunities, diversified agro-ecological conditions to produce cool season crops (above 2400 meters, day temperatures ranging from freezing to 16°C), mid altitude crops (1500 – 2400 meters, day temperatures from 16 – 30°C) and warm season crops (below 1500 meters, day temperatures above 27°C) (Wiersinga and de Jager, 2009). Vegetable production in the country’s fertile areas is one of a strategy envisioned to help realize the GTP. Tomatoes are among the vegetables identified in the Growth and Transformation Plan as a high value vegetable (Tefera and Tefera, 2013).

2.7. Concept of Nutrient Uptake and Function of Some Nutrients

Factors that affect nutrient absorption are type of ion, soil pH, solubility of ion, water, soil oxygen, temperature, and soil nutrient levels. Most of the nutrients that plants need are dissolved in water and then absorbed by the roots. Ninety-eight percent of these plant nutrients are absorbed from the soil solution, and only about 2 percent are actually extracted from soil particles by the roots (Flynn, 2010). In smallholder farming system, the causes of nutrient deficiency include high plant nutrient uptake, removal of entire crop residues, use of cattle dung as source of fuel energy for cooking, nutrient loss through leaching, P-fixation in acid soil and gaseous loss of N Aticho (2011) as cited by (Aticho *et al*., 2014).

2.7.1. Nitrogen (N)

Of the three primary macro nutrients, plants require N in the largest amounts. N enhances rapid growth, increases leaf size and quality (Tucker, 1999). N being a major nutrient for plants is constituent of chlorophyll (enable the process of photosynthesis) and used as building block of amino acids and then protein. It also involves in catalization of chemical responses and transportation of electrons and present in many major portions of the plant body. N imparts dark-green color in plants, promotes leaves, stem and other vegetative growth. Moreover, N produces rapid early growth, improves fruit quality, and enhances the growth of leafy vegetables. It enhances the uptake and utilization of potassium, phosphorous and regulates overall growth and development of plant (Tucker, 1999; Bloom, 2015; Hemerly, 2016; Alhrout, 2017).

The available forms of N for the plants are NH_4-N and NO_3-N which means (nitrogen in the ammonium and nitrogen in the nitrate form respectively) and contributes for synthesis of proteins. Soil concentrations of NO_3-N and NH_4-N influenced by biological activity; it also fluctuates with changes in temperature and moisture. Nitrate is easily leached from the soil with high rainfall or excessive irrigation. NH_4-N usually does not accumulate in the soil; as soil temperature and moisture conditions suitable for plant growth they also are ideal for conversion of NH_4-N to NO_3-N (Horneck *et al*., 2011**)**. Pepper plants were found to positively respond (by increasing canopy, number of flowers and fruits) to higher nitrogen concentrations than the usual norms for other crops (Chemicals, 2016).

N is mobile in plants; upon deficiency it slows down plant growth, yellowing of leaves (chlorosis) and gradual drying beginning at leaf margins of the lower leaf veins, the petioles bend and hang downwards, development of few flowers and fruit setting (Flynn, 2010; Chemicals, 2016). Too much N in a plant results succulent growth, very dark green color, weak spindly growth, and not much fruit (Flynn, 2010).

2.7.2. Phosphorus (P)

Phosphorus is the second most important plant nutrient next to N and essential for development of the roots and reproductive organs. It also contributes for cellular division and formation of energetic structures. It is needed for the seedling growth and establishment of the transplant; although plants actually use relatively small amounts of P when compared to N and K (Flynn, 2010; Chemicals, 2016). It is needed for photosynthesis, sugar and starch formation, energy transfer and movement of carbohydrates (Hamza, 2008).

Phosphorus is absorbed in the form of $H_2PO_4^-$ or HPO_4^{2-} ion. This complex does not leach readily from the soil and mobile in the plant once taken up from the soil. P is rapidly fixed with iron and aluminum when applied under acidic soil conditions and fixed as insoluble calcium phosphate in alkaline soils with Ca and unavailable to plants (Flynn, 2010; Simson and Straus, 2010). Excess P can induce N and micronutrient deficiencies such as Zn, Fe, and Co (Flynn, 2010). Phosphorous deficiency in plants causes too small and short branches, many undeveloped buds and less fruit, intense coloring, browning or purpling of foliage in some plants, thin stems, loss of lower leaves and reduced flowering (Hamza, 2008; Flynn, 2010; Chemicals, 2016).

2.7.3. Sulfur (S)

Sulphur is secondary macro plant nutrients and involve in protein synthesis. S is present in the structure of the amino acids cysteine and methionine, both of which are important components of proteins (Hamza, 2008). Thus, it was currently suggested to be applied as chemical fertilizer like P and N by blending with other essential plant nutrients depending on soil nutrient deficiency. Its fertilization encourages the uptake of N, P, K and Zn in the plant; which results in increased crop productivity. Additionally, application of S containing fertilizer is a feasible technique to alleviate the uptake of toxic elements like Na and Cl as they act antagonistic to each other; thus, its application is useful for increasing crop production and improves soil conditions for healthy crop growth (Zhang *et al*., 1999).

Sulphur deficiency was little practical importance decades ago. However, in Ethiopia the idea of S deficiency has raised in recent years by soil mapping. Land degradation, crop residue removal, clearing and burning of forests and other vegetation, crop uptake, and use of non-S fertilizers are major causes of sulfur deficiency in the Rift Valley (Itanna, 2005; Simson and Straus, 2010; ATA, 2015). Maintenance of the soil organic matter, utilization of subsurface inorganic S and proper management of soils should maintain the S status of the soils in the future (Itanna, 2005).

Sulphur is absorbed as $S0^{-}_{4}$ ion form and constituent of amino acids, which in turn are building blocks for essential proteins in the plant. S is not mobile in the plant; thus, deficiency symptoms include a light green to yellowish color of young leaves, small and spindly plants, retarded growth rate, and delayed maturity. S can be leached from soil with excess rain and irrigation (Flynn, 2010).

2.7.4. Zinc (Zn)

Like sulfur, Zinc is raised as deficient in the soil and need to be added as chemical fertilizers. It is predominantly taken up from the soil as a divalent cation, Zn^{2+}; however, in some of calcareous and high soil pH it is believed to be taken up as a monovalent cation $ZnOH^+$ (Anonyms, 2002; Flynn, 2010; Chemicals, 2016).

The role of zinc in the plant is either as a metal component of an enzyme or as functional cofactor of different enzyme reactions. Zn plays crucial role in plant metabolism as it influences the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome (Tisdale *et al*., 1984). Plant enzymes activated by Zn are contributed in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, regulation of auxin synthesis and pollen formation (Marschner, 1995). The regulation of the gene expression which are required for the tolerance of environmental factors causing stresses on plant growth and development are Zn dependent (Cakmak ,2000). Zinc also enhance the capacity for water uptake and transport in plants and reduce the adverse effects of heat and salt stress for short periods (Kasim, 2007; Disante *et al*., 2010).

In soils having low Zn levels, large applications of P will result zinc deficiency, likewise placement of large concentration of P in the row without adequate zinc will create Zn deficiency. This stands true in the plant itself in that high concentrations of P in the shoots inhibit zinc translocation. A typical symptom of zinc deficiency that has a dramatic effect on yield and quality is a symptom known as small leaf, which can be identified in any crop including hot pepper. Research shows that, zinc is required for the synthesis of tryptophan, which in turn is the precursor for the synthesis of IAA. In the absence of IAA, plant growth is stunted particularly the length of internode and leaf size; so that up on suboptimal level Zn causes stunted plant growth (Marschner, 1995; Cakmak, 2000; Anonyms, 2002).

In direct concern with pepper, zinc deficiency results little leaf (a reduction in size of leaves), short internodes, distorted or puckered leaf margins, and interveinal chlorosis of new growth in chili. Excessive zinc can appear as Fe deficiency (Flynn, 2010; Chemicals, 2016). The factors which affect the amount of zinc available in soil are pH, carbonate content, organic matter, soil texture and interaction between zinc and other trace elements, such as iron (Bukvic *et al.*, 2003). Zinc is important to membrane integrity and phytochrome activities

(Shkoinik, 1984); as well it is essential for the normal healthy growth of plants and plays a great role as a structural constituent or regulatory co-factor of wide range of enzymes in many important biochemical pathways (Kabata and Pendias, 2001; Grotz and Guerinot, 2006).

2.8. Growth, Yield Attributes and Yield of Hot Pepper Cultivars

2.8.1. Influence of hot pepper cultivars on some vegetative growth

According to Sibhatu *et al*. (2016), plant height significantly varied among hot pepper cultivars (Melka Zala, Melka Zhote, Weldele, Mareko Fana and local cultivar). Accordingly, Weldele recorded numerically the highest plant height, which however, was on par with Melka Zhote. While, the smallest plant height was recorded from Melka Zala cultivar. Similarly, Simon and Tesfaye (2014) reported no statistically significant difference among hot pepper cultivars with regard to plant height, branch number and stem diameter. Melese and Gebreslassie (2015) reported that Bako local was statistically similar with Mareko Fana (41cm) and Melka Awaze showed the smallest plant height (39.7cm).

2.8.2. Influence of hot pepper cultivars on phenological characters

Sibhatu *et al*. (2016) investigated five hot pepper cultivars in Tigray regional state and indicated that there was significant difference on days to 50% flowering among cultivars. The highest (70.11) and lowest (49.01) days to fifty percent flowering was observed in Melka Zala and Melka Shote, respectively; meaning that Melka Zala took longest duration to flower while Melka Shote flowered earlier. Earliness or lateness in the days to 50% flowering might have been due to their inherited characters and early acclimatization of the cultivar to the growing area. Similar result was obtained by Seleshi *et al*. (2014) who reported that days to flowering of hot pepper cultivars was significantly affected by the interaction effect of cultivar and location of the growing area.

In similar way, the result obtained during 2005/2006 cropping season showed that there was statistically significant difference among pepper Cultivars at ($p < 5\%$). The highest maturity date (one which matured late) was recorded from Mareko fana (128 days). However, it was statistically similar with Melka Awaze (127.670days) and Bako local (127.7 days). The lowest days to maturity (one which matured earlier) was recorded from Melka Shote (126.33 days). In 2006/2007 cropping season, all the cultivar of pepper showed statistically non-significant maturity dates; whereby the late and the early matured cultivar were Melka Shote and Bako local which were 119.66 days and 118.33 days, respectively (Melese and Gebreslassie, 2015)

Like days to flowering, days to maturity influenced significantly ($P<0.05$) by hot pepper cultivars whereby highest and lowest days to maturity were recorded in Melka Zala and Melka Shote cultivars respectively (Sibhatu *et al*., 2016). The result agrees with Gebremeskel *et al.* (2015) who reported that days to maturity were significantly affected by pepper cultivars (Mareko Fana, Melka Awaze and Melka Shote). Although, this result was contrasting to finding of Tibebu and Bizuayehu (2014) who revealed that days to maturity was not significantly different due to cultivars. An investigation made by Mebratu (2014), Aminifard *et al*. (2012), Tesfaw *et al*. (2013) revealed that days to flowering and maturity are influenced by the combination of fertilizer level, cultivar/genotype and environment.

2.8.3. Influence of hot pepper cultivars on yield attributes and yield

2.7.3.1. Pod number per plant

Alemu *et al*. (2016) evaluated four pepper cultivars (Bako local, Odaharo, Alaba local and Mareko Fana) at Gatto Kebele Farmer training Center (FTC) and reported there were highly significant differences ($P<0.01$) among cultivars in number of pods plant^{-1} in both cropping seasons. Bako local gave the highest number of pods plant^{-1} which is 113.2 and 53.6 in 2013 and 2014 cropping season respectively. Whereas, Halaba local yields the least number of pods plant^{-1} in both production seasons. In contrast to this finding, Delelegn (2011) reported, Bako local gave lowest number of pods plant^{-1} at Kechema nursery site while Weldele cultivar gave highest pods plant^{-1}. This may be as a result of environmental factors (Tesfaw *et al*., 2013). According to Yadeta *et al*. (2011) pods plant^{-1} was positively associated with total fruit yield. Simon and Tesfaye (2014) reported cultivars differed significantly in number of pods plant^{-1}, fruit length and fruit diameter. Mareko Fana cultivar gave significantly the highest pod length, pod diameter, seed number per pod and also the highest total biomass plant^{-1} than Melka Shote but Melka Shote cultivar had significantly the highest pod number plant^{-1}.

Similarly, Melese and Gebreslassie (2015) made an investigation on four hot pepper cultivars (Bako local, Melka Shote, Melka Awaze and Mareko Fana) at Tanqua-Abergelle woreda in Tigray region, and found statistically significant difference among the cultivars in the first year of the trial in relation to pods number plant^{-1}. The highest and lowest numbers of pod plant^{-1} were observed in Melka Awaze (46.30) and Bako local (24.70), respectively. However, there was no statistical difference in the finding obtained in second year rather than numerical difference. The variation at the same location in different season may be as a result of existing environmental factors during that time (Tesfaw *et al*., 2013). Some inconsistences among findings obtained by Alemu *et al*. (2016); Simon and Tesfaye (2014) and Melese and Gebreslassie (2015) may be due to difference between soil and atmospheric condition and seasonal variation of the locations.

2.7.3.2. Fruit length and diameter

Regarding pod physical quality in terms of diameter and length, the result obtained by Sibhatu *et al*. (2016) showed that, fruit length was significantly influenced by cultivars. Melka Shote gave the highest fruit length (11.00 cm) while the lowest was recorded on local (4.67cm). In terms of fruit diameter, the maximum value was registered on Mareko Fana; whereas, the minimum was obtained from Melka Zala. The finding of Gebremeskel *et al.* (2015); Seleshi *et al*. (2014); Tibebu and Bizuayehu (2014) also confirm these in the aspect of fruit length.

Similarly, as far as fruit length of the hot pepper cultivar is concerned, there was statistically significant difference among pepper cultivars in first cropping season. In accordance, Melka Shote which was statistically non-significant with Melka Awaze showed the highest fruit length. However, there were no significant difference on fruit length in the second production season; this shown cultivars alone not determine pod length rather than in combination with cropping seasons. Like fruit length, the finding obtained on fruit diameter was not similar throughout cropping season. In the first cropping season, the highest and lowest pod diameter was recorded from Mareko Fana (1.49 cm) and Melka Shote (1.0130 cm); although the result was not significant in the second cropping season (Melese and Gebreslassie, 2015).

2.7.3.3. Marketable yield

An investigation made by Alemu *et al*. (2016) revealed there were highly significant differences between treatment means in both 2013 and 2014 cropping season on fresh fruit yield. As the finding indicated, Bako local cultivar gave the largest fresh fruit yield which was 10.9 t/ha in 2013 and 10.5 t/ha in 2014 cropping season. In contrast, Odaharo was gave the least fresh fruit in both production season with the average yield of 5.03 t/ha and 3.5 t/ha in 2013 and 2014 respectively. This result opposes the finding of Delelegn (2011) who stated Bako local yielded 1.05 ton/ha while Odaharo recorded 0.79 ton/ha. Although, according to Tesfaw *et al*. (2013) marketable fresh fruit yield was found to increase in response to the combined action of N, P and cultivar rather than the individual effect solely. Thus, this shown yield is not the effect of single factor. Generally, the finding indicated the highest record for fresh fruit yield was recorded from Mareko Fana which 10.92 t was about ha^{-1} followed by the local cultivar (10.60 t ha^{-1}).

Sibhatu *et al*. (2016) revealed that cultivar exerted significant difference on marketable yield; the highest marketable yield (1.3 t/ha) was recorded from Melka Shote cultivar which yielded 44.97% over Mareko Fana which gave the lowest yield but not statically different from the other cultivars. The difference in marketable yield of those cultivars could be due to agro-ecological adaptability which is in line with the findings of Fekadu *et al.* (2008).

2.9. Nutrient Effects on Vegetative and Reproductive Growth of Hot Pepper

2.9.1. Effect of nutrients (N, P, S and Zn) on plant height and canopy

Aminifard *et al*. (2012) reported that the lowest plant height was recorded by cultivar not treated by N (control). Moreover, Akanbi *et al*. (2010) who reported that increased in height and leaf number of pepper plants were attributable to the supply of N contained in the applied fertilizer. Similarly, Khan *et al*. (2010); Mebratu (2014) revealed that plant height was significantly increased by increasing level of N. According to Khan *et al*. (2010) highest plant height was found with 150kg N ha^{-1} while the lowest plant height at first flowering (14.97 cm) was observed in control (0 kg ha^{-1}) unlike increment of P level on plant height which was not significantly increased.

Result obtained from the experiment conducted by Shil *et al*. (2013) indicated, the mean plant height ranged from 70.5 cm to 74.6 cm; where the highest result was observed in plots treated with Zn_3B_2 (3 kg Zn and 2 kg of B ha^{-1}) followed by $Zn_{4.5}B_1$ (4.5 kg Zn and 1 kg B ha^{-1}) whereas, the lowest was recorded from the experimental units not treated with Zink and Boron fertilizer or in treatment kept as control (Zn_0B_0).

In terms of branch number, Mebratu (2011) found nitrogen at 150 kg ha^{-1} produced branches that were higher than branches produced at 100 kg N ha^{-1}; however, the difference was statistically non-significant. Which is in line with Khan *et al*. (2010) who reported branches $plant^{-1}$ at first harvesting stage of *Capsicum* was significantly increased with the increase of N level as well as Aminifard *et al*. (2012) obtained the highest lateral stem length and number of lateral stems were obtained at 100 kg N ha^{-1} although no significant difference was found among 50, 100 and 150 kg N ha^{-1} on plant height (at vegetative and flowering stages).

These founding is evidenced by Chemicals (2016) who reported N is absorbed as NO_3^- or NH_4^+ from the soil and contributes for synthesis of proteins and the vegetative growth; pepper plants positively respond to higher nitrogen concentrations than the usual norms for other crops by increasing canopy, number of flowers and fruits.

2.9.2. Effect of nutrients (N, P, S and Zn) on reproductive growth

Tesfaw *et al*. (2013) indicated that the maximum number of days for 50% of the plants in the plot to flower was recorded on Melka Zala cultivar (99 days) in plots kept as a control (treated with 0 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1}). On the other hand, Mareko Fana was the earliest to flower (66 days) in plots treated with 0 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}. Furthermore, Sleshi (2011) reported that the cultivar Melkazala took longer period (71 days) to attained 50% flowering. For this study, the extra number of days required by Melkazala to flower might have been caused by environmental factors which may have resulted in extended and continuous vegetative growth.

Mebratu (2014) report indicated, regardless of cultivars, N rates from 0 to 50, 100, and 150 kg ha^{-1} resulted in about 4, 8 and 12 days delayed to reach 50 % flowering respectively. The highest level of N supply induced the highest number of days required for 50% of the plants to flower. This showed that days to flowering is delayed as fertilizer level increased. This result agrees with Lemma (2008) as cited in Tesfaw *et al*. (2013) who found the nutrient supply is also responsible for earliness or late start of blooming and the result showed plots that received higher levels of both fertilizers exhibited prolonged time to commence blooming.

Aminifard *et al*. (2012**)** found, N application accelerated the appearance of first flower up to a certain level. N deficiency retarded the vegetative as well as reproductive growth, which means it needs longer period to flower and fruit set. In contrary, the highest N level (150 kg ha^{-1}) also increased the number days up to flowering and fruit setting. Simon and Tesfaye (2014) reported increasing N application positively increased number of days taken to 50 % flowering, fruiting and maturity. Whereas, days to 50% flowering, fruiting and maturity decreased with increasing level of P fertilization. This showed that nitrogen had delayed flowering, fruiting and maturity while phosphorus accelerated flowering, fruiting and maturity period. Findings of Mebratu (2014); Aminifard *et al.* (2012) and Tesfaw *et al.* (2013) indicated that days to flowering was influenced by the combination of fertilizer level, cultivar/genotype and environment.

2.9.3. Effect of nutrients on pod size and pod number per plant

Fruit length and diameter is an important quality indicator in hot pepper. The thicker the fruit, the higher will be the surface area of the pod outweighing the contents of the seed when it is ground for spice (Adugna, 2008; Tesfaw *et al*., 2013).

Tesfaw *et al*. (2013) indicated that uptake enhancement as a result of application of increasing level of N and P fertilizer increased pod length. Thus, the maximum pod length (8.29 cm) was obtained from the cultivar Marekofana treated with 46 kg N kg ha^{-1} and 69 kg P_2O_5 kg ha^{-1}. Similarly, Simon and Tesfaye (2014) reported pod length is directly related with the amount of nutrients taken and the vegetative growth of the plant. N levels positively and significantly increased fruit length, fruit number $plant^{-1}$ and fruit diameter.

According to Tesfaw *et al*. (2013) and Mebratu's (2014) increasing N to 100 kg ha^{-1} resulted in the highest pod length (about 69% over the control). However, increasing N supply from 100 to 150 kg N ha^{-1} decreased pod length by about 21%. Adugna (2008) reported higher levels of N beyond the optimum lead to growth of more branches, ascend plant height, more number of pods, which could have increased competition for assimilate partitioning among the plant parts thereby reducing pod length and width.

Higher rates of N and P gave pods with larger cross-sections. The maximum cross-section (2.64 cm) of pods was recorded in the local cultivar treated with fertilizer rates of 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. The thinnest fruit (1.87cm) was obtained from the cultivar Mareko Fana which received 92 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1} (Tesfaw *et al*., 2013). From this finding there is no straight ascending or descending of pod size. So that there may be other factors that influence pod width out of fertilizer, season, environment and genotype; it may be due to uneven management and other systematic error during the establishment and measurement.

Finding obtained by Shil *et al*. (2013) indicated that, pod size (Pod length and width) also influenced Zn and B. Accordingly, the highest fruit length (7.21 cm) was found from plots treated with 3 kg Zn and 1 kg B ha^{-1} followed by 3 kg Zn and 2 kg B ha^{-1}; in contrast the lowest fruit length was obtained from plots not treated by Zn and B. Again, the fruit breath due to interaction ranged from 0.59 cm to 0.71 cm; where the highest result was observed in 3 kg Zn and 1 kg B ha^{-1} followed by 4.5 kg Zn and 2 kg B ha^{-1} and the lowest at the control.

2.9.4. Effect of nutrients (N, P, S and Zn) on pod yield

Proper fertilization of the required nutrients is fundamental for satisfactory crop growth and production. So that efficient application of the correct types and amounts of fertilizers at the right time and stage is an important part of achieving profitable yields (Mckenzie, 1998). To investigate the effect of nutrients specifically N and P on performance of different hot pepper cultivars, there were different experiment conducted at different location and season; however, there were virtually no experiment to test the response of sulphur and zinc globally.

The highest fresh fruit yield was recorded on Mareko Fana cultivar which was about 10.92 t ha^{-1} in treatments that received fertilizer both 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}, followed by the local cultivar (10.60 t ha^{-1}) which received 46 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} (Tesfaw *et al*., 2013). Similar result was reported by Mebratu *et al*. (2014) who reported the highest marketable yield obtained at 100 kg N ha^{-1} which was 267% higher than the control. This could be attributed to enhanced pod length, pod width, higher seed weight, seed number per pod and higher total dry pod weight $plant^{-1}$ obtained at this level. However, further increased nitrogen application from 100 to 150 kg N ha^{-1} reduced marketable yield by about 42%. In contrast, Aticho *et al*. (2014) report, 50 kg DAP and urea ha^{-1} for Marekofana cultivar production was statistically different and higher than the others which received 25, 75 and 100 kg ha^{-1}.

According to Mebratu *et al*. (2014), the decreased in marketable pod yield was attributed to excess N which produced excess foliage, reduces fruit size and marketable yield. Simon and Tesfaye (2014) revealed that pod yield of hot pepper responded positively to increasing P level. In this study it was also observed that the yield improvement due to P application was mainly attributed to the accompanying improvement in yield component as fruit number $plant^{-1}$, fruit length, fruit diameter, number of seeds per fruit and also leaf area index (LAI).

Like plant height, fruit length and breath, the result obtained from consecutive three years revealed, fresh fruit weight $plant^{-1}$ was varied significantly due to Zn levels. The highest fresh ripe fruit weight (35.5, 37.4 and 35.3 g $plant^{-1}$ for the first, second and third year, respectively was recorded from 3.0 kg Zn ha^{-1}; which was the highest and significantly different from the other levels (Shil *et al*. 2013).

The highest unmarketable yield was obtained at 150 kg N ha^{-1}; which is higher than the unmarketable yield obtained at control level by 88%. There were no significant differences in unmarketable yield at control and in other treatments. The highest unmarketable pod yield was obtained at the highest level of N, which might be due to the production of more number of branches and other vegetative organs that may have increased competition for photo assimilate among the pods and overcrowding of branches, which might have resulted more number of small-sized pods (Mebratu *et al*., 2014).

According to result obtained by Shil *et al*. (2013), there was significant interaction effect between Zn and B in case of yield of dry chilli and weight of ripe chilli plant^{-1}. The highest yield (1.14 t ha^{-1}) was recorded from experimental unit received 3 kg Zn and 1 kg B ha^{-1}, which was closely followed by 3kg Zn ha^{-1} and 2 kg B ha^{-1}, 4.5 kg Zn and 2 kg B kg ha^{-1} and the lowest (0.70 kg ha^{-1}) was obtained in control (0 kg Zn and 0 kg B) treatment.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The field experiment was carried out at Mehoni Agricultural Research Center (MhARC), under irrigation condition. The center is situated at about 678 km to the north of the capital, Addis Ababa, in Raya Azebo southern Tigray zone. As metrological class of the center indicated, geographically the area is located at 12° 41' 50" North latitude and 39° 42' 08" East longitude with an altitude of 1578 m.a.s.l. The site receives mean annual rainfall of 750 mm. The average minimum and maximum temperature of the site is 18 and 25°C, respectively. The soil textural class of the experimental area is clay loam with pH of 7.9.

3.2. Experimental Procedures

3.2.1. Treatment and experimental design

The experiment consisted of five blended (N-P_2O_5-S-Zn) + urea fertilizer rates, one without fertilizer as control and two selected hot pepper cultivars (Table 1). For a reference of N-P_2O_5-S-Zn which have percentage composition of 17.7N-35.3P_2O_5+6.5S+2.5Zn, the blanket recommendation of Urea and DAP for hot pepper production at Raya Azebo was used. The blanket recommendation of N and P, at Raya Azebo was 60 kg ha^{-1} (130.4 kg Urea ha^{-1}) and 10 kg ha^{-1} (22.9 kg P_2O_5) respectively (Teka, personal communication, 2017). So, to apply 22.9 kg P_2O_5 ha^{-1} in the form of NPSZn, 65 kg NPSZn ha^{-1} is required. When 65 NPSZn kg ha^{-1} is applied, 11.5 kg ha^{-1} of N was applied concurrently; thus, to apply the recommended N (60 kg ha^{-1}) in parallel with NPSZn, 48.5 N is left. So, the remaining N was applied in the form of urea which is 105 kg ha^{-1}. Accordingly, 65kg of NPSZn and 105 kg of Urea ha^{-1} were used as the reference. The rest levels of NPSZn + urea was arranged by adding and subtracting 30% and 60% of the rate used as a reference, consecutively (Table 2). Of the total N intended to be applied in the form of urea, 30.8% of each rate which are (13.2, 22.6, 32.3, 42 and 51.7 kg for 42.8, 73.5, 105, 136 and 168 kg of urea, respectively) were applied at transplanting with NPSZn and the rest was applied at 45 days from transplanting. The treatments were laid down in randomized complete block design (RCBD) with factorial arrangement (2 *6 = 12) with three replications.

Planting material: two commercial cultivars of hot pepper namely Melka Shote and Melka Awaze were introduced from Melkassa Agricultural Research Center (MARC). For the basis of cultivar selection, there was an adaptation trial conducted on different hot pepper cultivars (Melka Shote, Mareko Fana, Melka Zala and Melka Awaze) at Raya valley. The result revealed, the highest (353.43 q ha^{-1}) and the lowest (325.45 q ha^{-1}) marketable yield were obtained from Melka Awaze and Mareko Fana respectively. However, during demonstration of these cultivars Melka Shote cultivar has got a great acceptance by farmers due to the level of pungency, color and resistance to wilt disease. Thus, both Melka Shote and Melka Awaze cultivar was recommended for the farmers at that location (Gebremeskel *et al*., 2015).

Table 2. Description of treatment combinations of blended fertilizer with pepper cultivars

No.	Treatments		Nutrients concentration (in NPSZn + urea) kg^{-1}			
	Cultivars	Fertilizer NPSZn + urea Kg/ha	N	P_2O_5	S	Zn
1	MA	0	0	0	0	0
2		26 NPSZn + 42.8 Urea	24	9	1.7	0.65
3		45.5 NPSZn + 73.5 Urea	42	16	3	1.13
4		65 NPSZn + 105 Urea	60	23	4.2	1.63
5		84.5 NPSZn +136.5 Urea	78	30	5.3	2.11
6		104 NPSZn + 168 Urea	96	37	6.7	2.6
7	MS	0	0	0	0	0
8		26 NPSZn + 42.8 Urea	24	9	1.7	0.65
9		45.5 NPSZn + 73.5 Urea	42	16	3	1.13
10		65 NPSZn + 105 Urea	60	23	4.2	1.63
11		84.5 NPSZn +136.5 Urea	78	30	5.3	2.11
12		104 NPSZn + 168 Urea	96	37	6.7	2.6

MA = Melka Awaze cultivar, MS = Melka Shote cultivar

3.2.2. Description of the cultivars grown in Ethiopia

Pepper cultivars are different in terms of growth habit (erect, semi-erect and spreading), plant height, plant canopy, leaf width, leaf color, leaf shape, stem shape, stem color, branching and growth habit. In its inflorescence, it shows difference in maturity and number of days required from flowering to pod maturity. The pods also vary in their fruit position, fruit color at maturity and ripening, fruit position, fruit shape, fruit length, fruit width, fruit wall thickness, fruit shape at blossom end, level of pungency and seed color and number of seeds per fruit (MoARD, 2009). As described by MoARD (2009); MoANR (2016) hot pepper cultivars have some common features in terms of climatic requirements; in contrast, they also differ in yielding ability. As indicated by MoARD (2009), the actual yield performance of hot pepper cultivars ranged from 1.5 t ha^{-1} to 3.0 t ha^{-1}. From this, Melka Shote cultivar has the highest actual yield ranging from 2.5 to 3.0 t ha^{-1} as compared to the other cultivars. While Melka Awaze cultivar yields ranged from 2.5 – 2.8 t ha^{-1} (Table 3)

Table 3. Description of hot pepper cultivars

Cultivars	Environmental condition required					
	Altitude masl	Temp. (^{0}C)	Rain fall (mm)	Maturity days	Year of release	Yield ha^{-1} (tonne)
Melka Awaze	1000-1800	18/29	900-1300	100-110	2006	2.5 -2.8
Melka Shote	1000-1800	15/27	900-1300	110-120	2006	2.5 – 3.0
Mareko Fana	1200 - 2100	-	900-1300	120-135	1976	1.5-2.5
Bako Local	1200-1900	-	900-1300	130-145	1976	2.0-2.5
Melka Zala	1200-2100	-	900-1300	130-150	2004	1.7-2.8
Melka Dima	1000-2000	-	800-1100	100-120	2004	1.5-2.0
Melka Eshete	1000-2000	-	800-1100	100-120	2004	1.5-2.0

Source: EARO (2004); MoARD (2009); MoANR (2016)

3.2.3. Nursery preparation and raising of seedlings

Field for nursery bed was ploughed and well pulverized to make it friable. Three seed beds having dimension of each 10 m in length and 1 m in width were prepared. Seeds of hot pepper were drilled at seed rate of 800 g ha^{-1} by hand onto the nursery beds at inter-row spacing of 15 cm. In the nursery 10 kg P_2O_5 ha^{-1} in the form of NPSZn applied at sowing. After sowing, the beds were covered with dry grass mulch until emerged, and water was applied using watering can as needed. Fertilizer was applied at a rate of 10 kg N ha^{-1} in the form of urea (46% N) after thinning the seedling in order to produce vigorous, healthy and green seedlings. Two weeks before transplanting, water supply to the nursery reduced in order to acclimatize the seedlings and reduce transplanting shock. The seedlings then watered on the bed one day before to enhance easy uprooting and prevent damage. Well established seedlings (standard seedlings) having minimum of four and maximum of six true leaves were selected and transplanted (October 20, 2017) to the experimental field on ridges at the spacing of 70 x30 cm (EARO, 2004; Mebratu *et al*., 2014).

3.2.4. Field preparation, Designing and transplanting

The experimental land was properly cleaned and ploughed to loosen and pulverize until proper growing conditions attained. The experimental area was grouped against slope gradient into three virtually homogeneous groups called block; the blocks were partitioned into plots by considering all the treatments appear once per block. Each experimental plot has an area of 13.66m^2 (3.90 m length x 3.50 width) with the spaces between replications and plots were 1.5 m and 1 m respectively. The gross area of experimental area was 780.3 m^2 (57.8 m length * 13.5 width). The treatments were laid down in randomized complete block design (RCBD) with factorial arrangement (2 *6 = 12) with three replications.

Uniform, healthy and vigorous seedlings were transplanted to experimental field which took generally 58 days. Drip irrigation was intended to be used; however, the irrigation system was not functioning properly as a result the trial was irrigated two times per week for one month, then, once in every five to ten days interval using pipe.

3.3. Data Collected

3.3.1. Soil sampling and physicochemical properties analyzed

Before transplanting, soil samples were collected from the experimental site at depth of 0 - 15 cm (in which nutrient feeding lateral roots are occurred) (Ashilenje, 2013) with sampling auger following diagonal fashion from 20 sample spots. This author also indicated that pepper has deep taproots which can grow up to 40 cm deep with fibrous lateral roots that spread between 50 and 60 cm diameter on the top soil layer from 10 -20 cm depth. Then the collected samples were mixed thoroughly to take one composite sample. The composite soil sample was air dried, ground to pass through 2 mm sieve and analyzed for selected soil physicochemical properties such as available P (ppm), total N (%), CEC, EC, pH, OC (%) and soil texture (% clay, % sand and % silt) at Mekelle University and S (ppm) at Tigray Agricultural Research Institute. After harvesting, composite soil samples were taken from plots treated alike and analyzed for P (ppm), N (%) and, OC (%) and pH.

Accordingly, soil texture (percentage of sand, silt and clay) class was determined by hydrometer method (Berhanu, 1980) after dispersing soil with sodium hexametaphosphate. The result of analyzed soil physical properties indicated that clay, silt and sand proportion of the study area were 36%, 31% and 33%, respectively and classified as loamy soil. Total nitrogen was measured by Kjeldahl digestion of soil (copper sulphate-potassium sulphate catalyst). EC was measured on 1:2.5 ratio of soil to water extract with an EC meter. The pH was measured by pH meter. OC was determined by wet oxidation method of Walkley and Black (Hazeltonand Murphy, 2007) and converted to OM by multiplying the value of OC by correction factor 1.724 (Nelson and Sommers, 1982) as illustrated in (Table 4).

Table 4. Soil physical and chemical properties of the experimental area before transplanting

No	Parameter	Value	Methods used	Status	References
1	TN (%)	2.16	Kjeldahl	High	Horneck *et al*. (2011
2	Av. P (%)	0.0019	Olsen	Medium	Horneck *et al*. (2011)
3	CEC (cmol)	43.5	Ammonium acetate	Very high	
4	EC (dS/m)	0.12		Low salinity	Slavich and Petterson (1993)
5	S (ppm)	3.71	Turbidity methry	Low	Horneck *et al*. (2011)
6	OC (%)	1.82	Walkley& black	Low	Horneck *et al*. (2011)
7	OM (%)	3.14		Low	Horneck *et al*. (2011)
7	pH	7.3	pH meter	Neutral	Horneck *et al*. (2011)
8	Soil textural Class		Hydrometer		
	Clay	36			
	Silt (%)	31			
	Sand (%)	33			
	Soil textural class: Loam				USDA (1987)

%TN = percent of total nitrogen, Av.P. ppm = available phosphorus in parts per million, CEC (Cmolkg^{-1}) = cation exchange capacity in cent mole, pH= hydrogen power, % OC = percent of organic carbon, %OM = percent of organic matter, EC(dS/m) = electrical conductivity in Deci Siemen/meter

3.3.2. Growth and phenological variables of hot pepper

Data were collected from the three middle harvestable rows excluding the two border rows and one plant from the end of each harvestable row in both sides. Five plants were randomly sampled for the collected data on growth and yield attribute characters from the harvestable rows. While, for phenological and yield (marketable, unmarketable and total yield) data was taken from net plot area.

Plant height (cm): Plant height measurement was made from the soil surface to the top most growth points of plant part. The measurement was randomly taken from five sampled plants at the last harvesting and the average of them was taken.

Canopy diameter (cm): The mean value was taken at the last harvest by measuring diameter of the five sampled plants to both north to south and east to west direction.

Total leaf area (TLA cm^2): It was determined from five randomly taken plants at complete pod setting and the mean value of them were taken. TLA was obtained by measuring the length and width of five leaves for each five plants and counting the total number of leaves with respect to the plant. The leaf area was calculated and then multiplied by respective plant's total number of leaves to obtain the total leaf area using the formula developed by Swart *et al*. (2004):

LA= LL x LW x 0.69

TLA = LA x TNL Where: LA = Leaf area, LL= Leaf length, LW= Leaf width and

TNL = Total number of leaves

Leaf area index (LAI): Leaf area index refers to ground covered by the leaf. It was calculated from five randomly taken plants using the formula suggested by Sestak *et al.* (1971) and the average value was taken.

Leaf area index (LAI) = Leaf area in (cm^2)/Land area in cm^2

Above ground total biological dry weight plant^{-1} (g): This was recorded as dry mass of all the plant parts above the soil surface (pods, leaves and stems). It was the average of five randomly sampled plants at the end of harvesting period and dried at temperature of 105°C until constant weight obtained.

Number of primary branches plant^{-1}: It was obtained by counting the numbers of branches plant^{-1} which emerged from the main stem from randomly sampled five plants at final harvest and the mean of them were taken.

Number secondary branches plant^{-1}: It was obtained plant^{-1} by counting the numbers of branches that emerged from primary branches from randomly sampled five plants at final harvest and the mean of them were taken.

Days to 50% flowering: The number of days when 50% of the plants in the plots started blooming beginning from the days of transplanting.

Days to first harvest: The number of days from transplanting to the date of first harvest

3.3.3. Yield and yield related parameters

Number of fruits plant^{-1}: Mean number of red ripe and matured pods of randomly sampled five plants from central rows for each plot were counted at the first harvest.

Marketable dry pod yield (t ha^{-1}): During each harvest, the marketable yield from the net plot area of each plot was weighed. The color of the pod (red), absence of unacceptable defects from insects, free of disease or physiological disorder (including sun scald) and pod size (pods > 1 cm^3) were considered as marketable yield (Tsedal, 2004). The total marketable yield was the sum of successively harvested marketable pods which obtained in the way that pods were dried until easily brittle under a partial shade and weighed.

Unmarketable dry pod yield (t ha^{-1}): This was determined also during each harvest. Unmarketable pod yield from the net plot area of each plot was assessed. Pods that were undersized < 1cm^3 in size (Tsedal, 2004), damaged by birds, shriveled and discolored due to sun-scald were considered as unmarketable.

Total dry pod yield (t ha^{-1}): This refers to the cumulative pod yields obtained during all harvesting cycles and includes both marketable and unmarketable dry pod yield.

3.3.4. Physical quality of the pods

Pod length and width (cm): The length and width of randomly sampled five pods from each five selected plants were measured by ruler before the second harvest after the first harvest were made from fully red colored pods having full shape (non-shriveled).

Thousand Seed weight (g): Seed extracted from marketable pods and counted, weighed using sensitive balance.

3.4. Partial Budget Analysis

Partial budget analysis was used to organize experimental data and information about the total costs and benefits of various alternative treatments. It is also economic analysis used to answer which treatment is economically feasible by using partial budget, dominance and marginal analysis of each treatment. To undertake this, average yields hectare^{-1} for each treatment, the adjusted yields, the gross field benefit and the total costs were required. The price of dry pod pepper in the local market was 100.00 ETB kg^{-1} of dry pod.

Gross average dry pod yield (t ha^{-1}) (GADPY): Is average yield of each treatment hectare^{-1}

Adjusted yield (AY): Is the marketable yield adjusted downward by a 10% to reflect the difference between yield obtained under the management of researchers and yield of farmers (CIMMYT, 1988).

$$AY\ (t\ ha^{-1}) = GADPY - (GADPY * 0.1)$$

Gross field benefit (GFB) (ETB ha^{-1}): It was obtained by multiplying price from the farm that farmers get when they sale the adjusted yield. GFB = AY* farm gate price for the crop

Total variable cost: It is the cost of fertilizers (NPSZn + urea), labour costs for weeding/hoeing and seed costs.

Net benefit (NB) (ETB/ha): Was the difference between gross field benefit and total cost for each treatment. NB = GFB – total cost

Marginal rate of return (MRR %): was the ratio of change in net benefit to change in cost and expressed in percentage:

$$MRR = \Delta NB / \Delta TVC \text{ Or } MRR\ (\%) = \text{Marginal benefit} / \text{Marginal Cost} \times 100$$

3.5. Data Analysis

The collected growth, phenological, yield components, yield and physical pod quality data were subjected to analysis of variance using SAS software version 9.3. Significant treatment differences were separated using the Least Significant Difference (LSD) test at the alpha level of 5%.

4. RESULTS AND DISCUSSION

4.1. Growth and Phenological Response

4.1.1. Plant height

Plant height was significantly ($p<0.05$) affected by the interaction effect of cultivar and fertilizer rates (NPSZn + urea). It was also highly significantly ($p < 0.01$) influenced by the main effect of both cultivars and NPSZn + urea (Appendix Table 1). The longest plant height (61.27 cm) (which is higher by 70 % than the shortest one) was recorded from combination of Melka Awaze cultivar with 104 kg ha^{-1} NPSZn + 168 kg ha^{-1} urea. While the shortest (36 cm) was recorded by interaction of Melka Shote with control (0NPSZn + urea kg ha^{-1}) (Table 5). This might be attributed to the function of genetic characteristics, response or adaptability of cultivars to the environment and fertilizer rates.

Increasing in plant height while NPSZn + urea rate increased might be attributed to nitrogen which contributes for plant elongation and initiating growth promoting hormones (IAA) similar to that of Zn and protein synthesis. Evidently, N is component of amino acids and chlorophyll which is the primary light harvesting pigment for photosynthesis; plant height is positively responded to the application of this nutrient (Bhuvaneswari *et al*., 2014). Zinc has also a great role in increasing the length of internode (elongates plant height) and protein synthesis (Marschner, 1995; Cakmak, 2000) thereby plant height. P is responsible for cell division and enhance nutrient uptake by encouraging root growth (Flynn, 2010; Chemicals, 2016). Zaman *et al*. (2011) revealed that plant height increased with increasing the levels of sulfur up to 45 kg ha^{-1} beyond which no significant increment was there. Hassaneen (1992) found sulfur application plays a great role as a soil amendment to improve the availability of nutrients such as P, K, Zn, Mn and Cu which in turn enhance plant growth.

The maximum plant height might be due to cell division and formation of new tissues which are highly linked with growth promoting nutrients particularly N, P and Zn (Wahocho *et al*., 2016). Zinc is essential for tryptophan synthesis which is a prerequisite for auxin formation, therefore amount of auxin decreases with zinc deficiency (Pedler *et al*., 2000) meaning that application of sufficient Zn alleviates this problem and brings health and vigorous growth of the plant. Besides, application of zinc was found to increase the green pigments of necrotic leaf of plants and contribute for increment of photosynthetic rate and plant growth (Srivastava and Singh, 2003). Gurmani *et al*. (2012) reported that the highest sugar and protein contents were observed from the application of 15 mg Zn kg^{-1} of soil followed by 10 and 5 mg Zn kg^{-1} of soil which in turn increases the growth of the plant.

In line with this, Bhuvaneswari *et al*. (2014) reported application of nitrogen fertilizer at the levels of 100 and 150 kg N ha^{-1} produced the tallest plant. Similarly, Aminifard *et al*. (2012) reported the highest plant height (41.67 cm) at reproductive stage was recorded by cultivar received 150 kg N ha^{-1}. Wahocho *et al*. (2016) revealed growth characters of chilies were significantly affected by N levels and cultivars whereby the interaction effect of 250 kg N ha^{-1} and Longi cultivar showed maximum plant height. Furthermore, plant height of hot pepper Simon and Tesfaye (2014) and snap bean Wossen (2017) responded positively and significantly to increasing level of N and P. Rwiza and Kisetu (2014) reported the tallest plant height from sweet pepper treated with NPK fertilizer as compared to control.

4.1.2. Canopy diameter

Average canopy diameter was significantly ($p<0.05$) influenced by interaction effect of cultivars and blended fertilizers doses. It was also highly significantly ($p<0.01$) affected by both the main effect of cultivars and NPSZn + urea rates (Appendix Table 1). Widest canopy diameter (59.63 cm) was obtained from interaction of Melka Awaze with 104 NPSZn + 168 urea kg ha^{-1} which is significantly at par with the interaction of Melka Awaze cultivar with 84.5 NPSZn + 136.5 urea kg ha^{-1}. In contrast, the narrowest mean value of canopy diameter was recorded at interaction of Melka Shote with control. At this rate, result recorded from Melka Awaze (42.5 cm) was statistically similar with widest canopy obtained at interaction effect of Melka Shote with 84.5 NPSZn + 136.5 Urea Kg ha^{-1} of fertilizer rate (Table 5). The wider canopy diameter observed from Melka Awaze (49.37 cm) cultivar is higher than the narrower canopy diameter obtained on Melka Shote cultivar (45.67 cm) by about 8%. In case of main effect of NPSZn + urea, the widest canopy (52.62 cm) was obtained when cultivars treated with 104 NPSZn + 168 urea kg ha^{-1}, followed by cultivars treated by 84.5NPSZn+136.5urea kg ha^{-1} (52.43 cm). While the narrowest canopy (41.13 cm) was recorded from the experimental units kept unfertilized (control). As responses observed on other growth indicators (plant height and number of branches), the failure of canopy diameter of hot pepper cultivars to be equal at the same rate of nutrients might attributed to inherent characteristics of the cultivars and extent of adaptability to environmental conditions.

Tucker (1999) reported shortage of P resulted in stunted growth, dark green leaves with a leathery texture and reddish-purple leaf tips and margins; while, the availability of this nutrient promotes the growth of branches. Zn is important to promote the plant growth as it is required for the synthesis of tryptophan (Alloway, 2004), which is a precursor of growth promoting hormone IAA (Brennan, 2005). Moreover, Zn has a regulatory influence on stomatal opening and CO_2 intake, possibly as a constituent of Carbonic anhydrase (Sharma *et al.,* 1995). Zinc is effective in plant nutrition for the synthesis of plant hormones and balancing intake of P and K inside the plant cells which in turn increases plant growth and yield (Shukla *et al*. 2009).

Musie *et al*. (2015) showed Melka Awaze gave maximum canopy diameter. In similar way, as cited in Musie *et al*. (2015), MoARD (2006) reported the canopy diameter of Melka Awaze variety is 61 cm. Matta and Cotter (1994) reported that application nitrogen promotes vegetative growth, leaf area, photosynthetic capacity and better partitioning of assimilate towards the fruits as compared to those not received nitrogen. Bhuvaneswari *et al*. (2014) indicated as nitrogen plays a key role in the preparation of starch in leaves and production of amino acids; it increases the vegetative growth of plants. Canopy diameter is not only the influence of plant nutrients alone rather greatly influenced by growth habit of the cultivars which is mainly governed by genetic make-up of the cultivars (Herison *et al*., 2014). As cited in Bhuvaneswari *et al*. (2014), Basela and Mahadeen (2008) reported N is the main constituent of all amino acids in proteins and lipids and structural compounds of the chloroplast. Therefore, it encourages the process of photosynthesis and promotes the growth of branches.

In agreement to this, Ashebre (2016) reported the widest canopy diameter in plants which received 61.5 kg N ha^{-1} + 69 kg P_2O_5 ha^{-1}, 41 kg N ha^{-1} + 46 kg P_2O_5 ha^{-1} and 82 kg N ha^{-1} + 92 kg P_2O_5 ha^{-1} with the combination of 5 t ha^{-1} of farm yard manure. Also, Gurmani *et al*. (2012) reported the highest chlorophyll, sugar and protein contents, which in turn enhanced the plant growth when 15 mg Zn applied to one kg of soil.

4.1.3. Total leaf area and leaf area index

Total leaf area (TLA) was significantly ($p<0.05$) affected by the combined effect of cultivars and fertilizer doses. Similarly, it also significantly ($p<0.05$) influenced by the main effect of cultivars and highly significantly ($p<0.01$) by the rates of NPSZn + urea. Furthermore, LAI was affected significantly ($p<0.05$) by interaction effect of both factors. The main effect of cultivars and fertilizer (NPSZn + urea) rates, exerted highly significant ($p<0.01$) difference on LAI (Appendix Table 1). Thus, the mean maximum TLA (9184.4 cm^2) was recorded when Melka Shote cultivar combined with 104 NPSZn + 168 urea kg ha^{-1}. This is statistically at par with the interaction effect of both Melka Awaze and Melka Shote cultivars with 84.5 NPSZn + 136.5 urea kg ha^{-1} and Melka Awaze with 104 NPSZn + 168 urea kg ha^{-1} with corresponding mean value of 8975.3 cm^2, 8775.8 cm^2 and 7797.1 cm^2. While the lowest value (4321.1 cm^2) was obtained when Melka Awaze cultivar kept unfertilized (Table 5).

Similarly, LAI was significantly influenced by the interaction effect of cultivars and NPSZn + urea rates in which the maximum value (5.57) was recorded when Melka Shote was combined with 104 NPSZn + 168 urea kg ha^{-1}. Whereas the lowest LAI (2.25) was recorded from the interaction of Melka Shote with the control (0kg NPSZn + urea kg ha^{-1}) which was not significantly different from the combination of both Melka Awaze and Melka Shote with 26 NPSZn + 42.8 urea kg ha^{-1} and Melka Awaze alone with 45.5 NPSZn + 73.5 urea kg ha^{-1} and the control (Table 4). The result obtained in both variables (TLA and LAI) might be attributed to the function of the applied nutrients, inherent characters of the cultivars and agro-ecologies of the study area.

Number of leaves and LAI were significantly affected by N rates whereby an increase in N promotes cell division and branching which in turn increases TLA and LAI (Simon and Tesfaye, 2014). The top TLA plant^{-1} obtained at higher rates of N might be attributed to the rationale that enhanced vegetative growth of the plant due to the contribution of N to protein synthesis which resulted in more number of leaves and larger leaf area. Nitrogen and sulfur have great contribution in the synthesis of proteins; thus, application of these nutrients in plants are highly inter-related (Jamal, 2010) and encourage plant vegetative growth. S has a great role in the formation of amino acids methionine (21% S) and cysteine (27% S), synthesis chlorophyll (enhance the process of photosynthesis) thereby plant growth and development (Jamal, 2009). Zinc deficiency causes interveinal chlorosis of the youngest leaves and reduces the chlorophyll content and leaf size (Tucker, 1999). Similarly, zinc deficiency in plants resulted in stunted growth, smaller leaf and fruit sizes and reduces the leaf area of the plant (Shukla *et al*., (2009).

Zinc is essential element for crop production and required for carbonic enzyme synthesis, present in all photosynthetic tissues and required for chlorophyll biosynthesis (Ali *et al*., 2008; Mousavi, 2011). These contribute for the growth of plants in terms of plant height, leaf number and leaf size. Since Zn is required for the synthesis of tryptophan which is a precursor for IAA synthesis (Alloway, 2004); thus, it has an active role in the production of auxin which initiate new tissue growth (Brennan, 2005). In dicot plants Zn deficiency reduces leaf size and number of leaves (Gokhan, 2002). Presence of Zn in blended fertilizers might stimulate the growth of hormones such as IAA which is mostly responsible for plant growth (Ram and Katiyar, 2013).

In general, both total leaf area and leaf area index which are highly inter related might be the function of nutrient applied and inherent characters of the cultivars. In accord to this, cultivars differed significantly in number of leaves in which the cultivar Melka Shote gave the highest number of leaves plant^{-1} (Simon and Tesfaye, 2014). The highest total number of leaves recorded at the highest rates of nutrients, particularly nitrogen (Mebratu, 2014; Ayodele *et al*., 2015) which directly implies the largest total leaf area and leaf area index of the plant.

Likewise, the maximum number of leaves plant^{-1} was recorded at the highest level of NP, while the least was recorded at the control (Akram *et al*., 2017).

4.1.4. Above ground total dry biomass

Above ground total dry biomass was significantly ($p<0.05$) influenced by interaction effect of cultivars and NPSZn + urea rates. It also highly significantly ($p<0.01$) influenced by main effect of fertilizer (NPSZn + urea) rates. However, it was not affected significantly ($p \geq 0.05$) by cultivars (Appendix Table 1). The highest (121.13 g) and the lowest (65.13 g) total dry biomass were recorded at the combination of Melka Shote with 84.5 NPSZn + urea kg ha^{-1} and control respectively (Table 5). In case of main effect of fertilizer rates, the maximum total dry biomass (119.17 g) was recorded from the cultivars treated with 84.5NPSZn + urea kg ha^{-1}. While the lowest (71.58 g) was recorded from the control.

The concentration range of N, P, S and Zn in dried plant tissues from the absorbed nutrient concentration accounts for 1-5%, 0.1 – 0.5 %, 0.1 – 0.4% and 25 – 150 ppm respectively (Jones and Olson-Rutz, 2016). This implies, dry biomass yield is positively related with nutrient taken up from the growing media. Moreover, total biomass was positively responded to NP rates whereby the maximum value was recorded from the application of 92/69 NP_2O_5. While the least biomass was recorded from unfertilized experimental units (Wossen, 2017). Kryzanowski (2005) reported that P is abundant in the actively growing tissue and about 25 % of their total dry weight. Normal plant growth cannot be achieved without P in which the rate required varies with cultivars, location and season. This is because of the involvement of P in physiological activities of plants like sugar and starch formation and accumulation, energy transfer and movement of carbohydrates (Hamza, 2008). P activates coenzymes for amino acid production which is precursor for protein synthesis and increases dry matter accumulation (Tucker, 1999).

Both S and N contribute for synthesis of proteins and as their rate increased the dry mass of the plants also increases (Horneck *et al*., 2011**)**. Sulphur has a great role in the formation of amino acids methionine and cysteine. It also involves in synthesis of proteins and chlorophyll (enhances photosynthesis thereby plant growth by encouraging the accumulation of dry matter and growth of protoplast) (Jamal, 2009). Zinc is important component of enzymes for protein synthesis and energy production and it also maintains the structural integrity of biomembranes (Shukla *et al*., 2009). Application of Zn at 10 and 15 mg kg^{-1} of soil increased chlorophyll, sugar, soluble protein and catalase activity in leaf of tomato cultivars which gives rise to production of higher biomass (Gurmani *et al*., 2012).

NPSZn + urea rates influenced the above ground total biomass yield of the hot pepper cultivars positively up to a certain level in which the cultivars responded in different ways even at the same rate of fertilizer levels. This might be due to the genetic makeup of the cultivars and in combination with nutrient NPSZn + urea. Similarly, the interaction effect of N, P and variety significantly influenced dry biomass yield. In line with this finding, the maximum dry biomass yield was obtained from cultivars which received 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} (Tesfaw *et al*., .2013). By this author, the minimum dry biomass yield was recorded on Melka Zala with fertilizer levels of 0 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1}. Application of nitrogen increased total biological dry mass compared to the control (Mebratu, 2014). Furthermore, total biomass of hot pepper cultivars responded positively to increasing N and P level (Simon and Tesfaye, 2014). Plots treated with 30 kg P_2O_5 ha^{-1} produced higher dry shoot weight than those of the plots with P_2O_5 at 45 and 60 kg ha^{-1} and control (Idowu *et al*., 2013). Pattanashetty (1985) reported the application of 12.5 kg ha^{-1} of sulphur had a positive effect on the biomass production and yield of coriander with higher levels of N and P fertilizers as cited in (Poornima, 2007).

Table 5. Interaction effect of cultivars and fertilizer rates on plant height, canopy diameter, total leaf area, leaf area index and above ground total dry biomass

Treatments		Vegetative Growth characters				
Cltv	NPSZn + urea kg ha^{-1}	PH (cm)	CD (cm)	TLA (cm^2)	LAI	AGTDB (g)
MA	0	49.20^{ab}	42.50^{cd}	4321.10^{f}	2.51^{ef}	78.03^{fg}
	26/42.8	57.27^{ab}	41.90^{cd}	6024.30^{cdef}	2.65^{def}	76.23^{gh}
	45.5/73.5	50.53^{ab}	49.53^{bc}	4555.10^{f}	2.87^{cdef}	94.30^{de}
	65/105	57.13^{ab}	47.87^{bcd}	6754.60^{cde}	3.5^{bcde}	96.60^{cd}
	84.5/136.5	57.47^{ab}	54.80^{ab}	8975.30^{ab}	3.83^{bc}	117.10^{ab}
	04/168	61.27^{a}	59.63^{a}	7797.10^{abc}	3.33^{bcde}	107.90^{bc}
MS	0	36.00^{c}	39.77^{d}	5143.00^{ef}	2.25^{f}	65.13^{h}
	26/42.8	46.13^{bc}	44.00^{cd}	5338.20^{def}	2.81^{cdef}	87.70^{defg}
	45.5/73.5	57.13^{ab}	44.73^{cd}	7042.20^{bcde}	3.58^{bcd}	82.60^{efg}
	65/105	54.20^{ab}	49.87^{bc}	7258.60^{abcd}	3.93^{b}	$89..28^{def}$
	84.5/136.5	54.47^{ab}	50.06^{bc}	8775.80^{ab}	4.16^{b}	121.13^{a}
	04/168	55.27^{ab}	45.60^{cd}	9184.30^{a}	5.57^{a}	93.60^{de}
LSD		12.13	8.36	2003.9	1.02	12.79
CV (%)		8.72	8.16	12.13	16.43	8.43

Means within columns followed by different letter (s) for each variable are significantly different *($p<0.05$)*

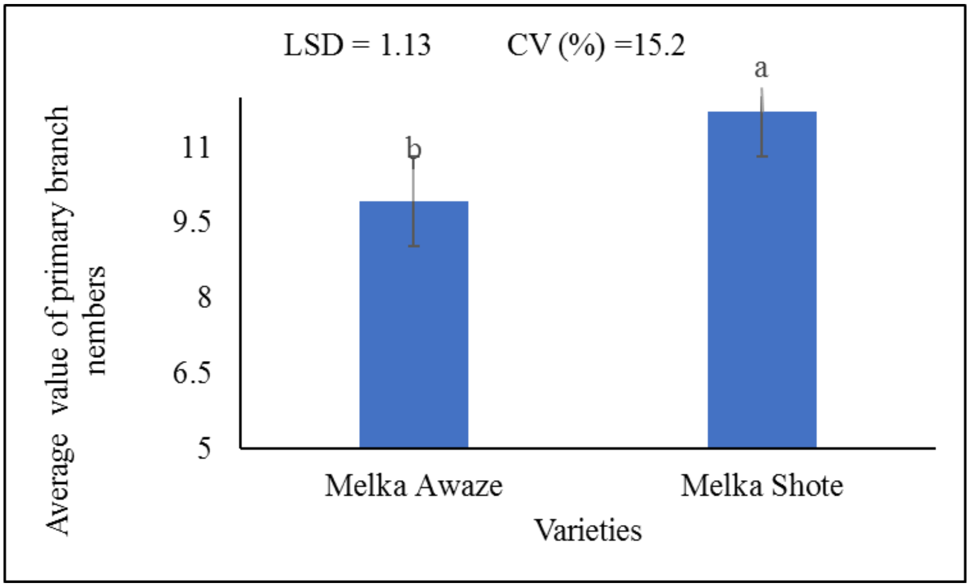
Cltv = Cultivars, MA = Melka Awaze, MS = Melka Shote, PH = Plant height in cm, CD = Canopy diameter, TLA = Total leaf area in cm^2, LAI = Leaf area index, AGTDB = Above ground total dry biomass.

4.1.5. Number of primary branches per plant

Mean number of primary branches plant^{-1} was highly significant *(P<0.01)* differed between cultivars. However, it was not significantly ($p \geq 0.05$) affected by main effect of NPSZn + urea and the combined effect of cultivars and fertilizer doses (Appendix Table 1). The highest and the lowest average number of primary branches were recorded from Melka Shote (11.71) and Melka Awaze (9.92), respectively. Melka Shote produced primary branches that were higher by about 18% than branches produced by Melka Awaze (Figure 1). While, the average number of primary branches were not significantly ($p \geq 0.05$) affected by fertilizer (NPSZn + urea) rates. In accordance, numerically the highest number of primary branches (11.43) was recorded at fertilizer rate of 65 NPSZn +105 urea kg ha^{-1}. In contrast, the lowest primary branch number was observed from the control (Figure 2).

The difference between cultivars on primary branches plant^{-1} might be due to genetic variation and difference in requirements of edaphic and atmospheric conditions. MoARD (2009) indicated the presence of significant variation among pepper cultivars in terms of growth habit, plant height, canopy growth, leaf size, branching habit which are influenced by the inherent characters of the cultivars, space availability, nutrient availability and weather condition. Similarly, Lemma *et al.* (2008) as cited in Kahsay (2017) reported that number of branches per plant, canopy, plant height, number of fruits per plant, days to maturity, dry fruit yield per plant and fruit length were significantly affected by cultivars.

This finding might be due to the difference in inherent characters of hot pepper cultivars and their response to the environment. In agreement with this study, Tesfaw *et al.* (2013) reported that cultivar is the major factor responsible to influence the number of primary branches. Also, Delelegn (2011) stated that both primary and secondary branches were influenced by cultivar, location and their interaction. In addition, Herison *et al*. (2014) found significant variation among tomato cultivars on number of branches. In contrast, Biramo (2016) reported that the numbers of both primary and secondary branches were not significantly affected by tomato cultivar.



Means followed by the different letters are significantly different *($p<0.05$)*

Figure 1. Main effect of hot pepper cultivars on primary branches plant^{-1}

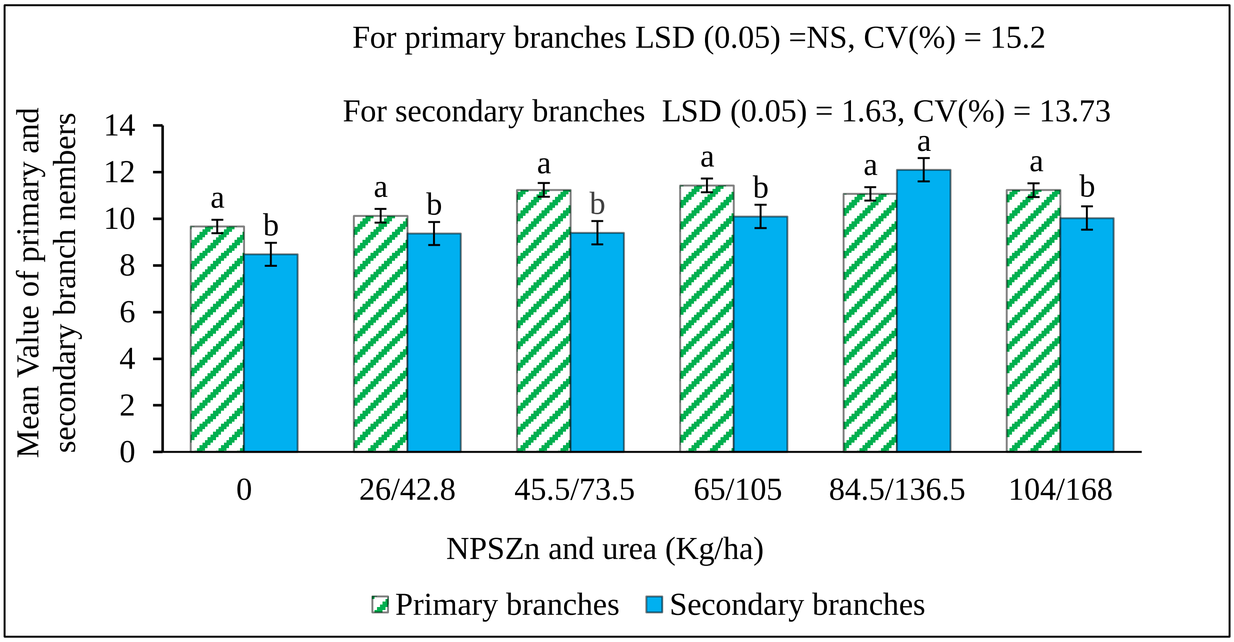
4.1.6. Number of secondary branches $^{-1}$

Secondary branches were highly significantly ($P<0.01$) influenced by the main effect of NPSZn + urea levels. It is the exact reverse of the primary branches in that secondary branches were not significantly *($P\geq 0.05$)* affected by cultivars unlike primary branches (Appendix Table 2). Accordingly, the maximum (12.10) mean value of number of secondary branches plant^{-1} was obtained at 84.5 NPSZn + 136.5 urea kg ha^{-1}; whereas the minimum (8.48) secondary branches were obtained at control level (Figure 2).

NPSZn + urea rates positively increased secondary branch number of hot pepper cultivars up to a certain level. This might be due to N at relatively highest rate which is responsible for encouraging vegetative growth and development of chlorophyll in plant leaves for successful photosynthesis. It might also be due to applied Zn which plays a great role in endogenous hormone synthesis particularly auxin like that of N. Apparently, N, S and Zn application also involve in protein synthesis and meristematic tissues initiation through hormonal synthesis which initiates a greater number of buds and hence more number of branches plant^{-1} (Tucker, 1999). Nitrogen imparts dark-green color in plants and promotes the growth of leaves, stem and other vegetative growth. Moreover, N produces rapid early growth through enhancing the uptake and utilization of K and P (Bloom, 2015; Hemerly, 2016).

Phosphorous involved in synthesis of carbohydrates (by photosynthesis) and in decomposition of carbohydrates (throgh respiration) processes and generates energy (Tucker, 1999); this energy helps plant growth positively. The increased branch number at the highest level of NPSZn + urea could also be attributed to Zn. Application of zinc is important for plant as a metal component of many enzymes or as a functional structural or regulatory cofactor for photosynthesis, protein production, cell division and the maintenance of membrane structure. Moreover, Zn application enhances water uptake and transport in plants and reduces the adverse effects of heat and salt stress for short periods as compared to plants not received Zn (Marschner, 1995). This in turn leads to favoring plant growth particularly branching and stem extension.

Application of NPSZn + urea contributes for enhanced sturdy and health of entire plant growth and root growth which enhance the uptake of water and nutrients as compared to the lower rates of fertilizers and unfertilized ones. In agreement with this, Mebratu (2011) found that branch numbers were highly significantly and positively influenced by N. Biramo (2016) reported that application of NP + bioslurry increased the number of secondary branches of tomato cultivars. Also, Ashebre (2016) obtained significantly the highest number of secondary branches through application of 82 kg N ha^{-1} + 92 kg P_2O_5 ha^{-1}+2.5 t ha^{-1} FYM. Also, Wossen (2017) reported a greater number of branches from experimental units which received 92/69 NP_2O_5 kg ha^{-1} (6.67) as compared to all rates of blended fertilizer NPK (which included all levels ≤ 300 Kg NPK ha^{-1}) and the lowest by the control treatment on snap bean.



Means followed by different letter/s for each variable are significantly different *($p<0.05$)*

Figure 2. Main effect of NPSZn + urea rates on number of primary and secondary branches of hot pepper

4.1.7. Days to 50% flowering

Days to 50% flowering was highly significantly ($p<0.01$) affected by interaction of cultivars and fertilizer (NPSZn + urea) rates. The main effect of NPSZn + urea, and cultivars exerted highly significant ($p<0.01$) and significant ($p<0.05$) difference on days to 50% flowering, respectively (Appendix Table 2). The result indicated that the combination of Melka Awaze cultivar with NPSZn + urea at the rate of 104 NPSZn + 168 urea kg ha^{-1} and 84.5 NPSZn + 136.5 urea kg ha^{-1} prolonged days to 50% flowering (both 99.33 days)., However, the above indicated fertilizer rates didn't affect Melka Shote cultivar. In contrast, Melka Awaze cultivar came into flowering earlier when interacted with plots not received fertilizer which on average took 87 days to commence flowering as illustrated in Table 6.

Guohua *et al*. (2001) and Simon and Tesfaye (2014) found that blooming was inhibited with fertilizer containing highest level of N and micro nutrient particularly Fe and Zn supply due to transformation of assimilates towards vegetative growth rather than reproductive growth. Tesfaw *et al*. (2013) reported coming to flowering stage of vegetable crops are linked to genetic factors, nutrient rates and environment (particularly temperature). Also, Alemayehu and Jemberie (2018) reported NPS rate, cultivar and location as well as their two, and three way interactions affected highly significantly flowering and maturity dates of potato. Thus, increasing NPS fertilizer rates delayed days of potato flowering. In contrast, Local cultivar without NPS fertilizer flowered earlier than the other two improved potato cultivars without NPS fertilizer. Kelly (2009) reported phosphorous accelerate normal bud and bloom development as it stimulates root growth and the uptake of plant nutrients and water. Uchida (2000) revealed that nitrogen and phosphorous deficiency causes early stunted flowering in some crops, which resulted in a significant reduction in yield and quality latter on.

Variation in 50% days to flowering attributed to not only the individual action of nutrients and cultivars but also their interaction. Thus, increasing the rates of NPSZn + urea prolonged the number of days required to bloom due to parallel increment of nitrogen. While, plants not fertilized with NPSZn + urea showed stunted vegetative growth and early flowering (forced flowering). This in turn resulted in small sized pods which mostly are not physically attractive and are categorized as unmarketable.

In agreement with the results of the present work, Mebratu (2014); Delelegn (2011); Aminifard *et al*. (2012) reported, days to flowering and maturity are influenced by interactive effect of fertilizer level, cultivar and environment. Also, Wahocho *et al*. (2016) found, the maximum number of days to commence flowering were observed in Kunri 1 cultivar at N level of 250 kg ha^{-1}; although, the minimum days to flower initiation was recorded from Nagina at 0 kg N level. The increasing levels of N delayed flowering whereby maximum duration noted for completing 50 percent flowering was observed at 120 kg N ha^{-1} (Manoj *et al*., 2013). Similarly, Tesfaw *et al*. (2013); Simon and Tesfaye (2014) showed number of days required to 50% flowering was influenced by interaction effect of N, P and cultivar.

4.1.8. Days to first harvest

Days to first harvest was significantly (*$p<0.05$*) influenced by interaction effect of cultivars and fertilizer rates (NPSZn + urea). Also, it was highly significantly *($p<0.01$)* affected by both main effect of cultivars and NPSZn + urea rates (Appendix Table 2). The interaction of Melka Shote with the control (0 kg ha^{-1} of fertilizer) significantly delayed days to first harvest (177.33 days). This finding is at par with the combination of Melka Shote with both 104 NPSZn + 168 urea kg ha^{-1} (175.67 days) and 84.5 NPSZn + 136.5 urea kg ha^{-1} (173.67 days) and Melka Awaze with the control fertilizer (173.33 days). While the interaction of Melka Awaze cultivar with 45.5 NPSZn + 73.5 urea kg ha^{-1} shortened days to first harvest (159.67 days) which is statistically similar with the combination of Melka Awaze with 65NPSZn + 105 urea kg ha^{-1} (Table 6). The prolonged days to first harvest recorded from unfertilized cultivar (Melka Shote) might be because phosphorous aids root development, flower initiation, seed and fruit development, so that, lack of P delayed maturity and poor seed and fruit development (Uchida, 2000; Kelly, 2009). Furthermore, nitrogen deficiency causes stunted growth and decrease fruit number and size; whereas high nitrogen level can stimulate excessive vegetative growth which can delay fruit setting and maturation (Sainju *et al*., 2003). Also, zinc plays an important role in seed development and zinc-deficient plants show delayed maturity (Shukla *et al*., 2009).

Increasing N application extended number of days required for pod maturity; whereas days to fruit maturity decreased with increasing P level up to some level (Simon and Tesfaye, 2014). Also, Brady and Weil (2002) reported that phosphorous contributes to flowering and hastens maturity of crops due to its involvement in carbohydrate synthesis, accumulation and respiration. Moreover, as cited in Simon and Tesfaye (2014), Michael (2003) indicated that application of N fertilizer is beneficial to vegetative growth and prolongs flowering, fruiting and maturity period.

Both unfertilized plots and those fertilized with the highest rate of NPSZn + urea prolonged (delayed) days to first harvest of red pods. This might be because optimum amount of P accelerates pods maturity; in contrast its deficiency causes stunting and early flowering; but, delays the maturity of pods and coming to red bright color. On the other hand, continuous increment of N rate diverts photo assimilate towards vegetative growth and prolongs the maturity of pods. To the opposite, shortage of nitrogen causes stunted plant growth and earlier flowering and pod setting. However, the pods stay green and unmatured due to shortage of photo assimilate for a longer period of time.

This finding agrees with some previous research findings. Increasing levels of N delayed the period required for fruit setting and fruit ripening (Manoj *et al.*, 2013). Alemayehu and Jemberie (2018) reported increasing of NPS fertilizer level increased days to maturity of potato cultivars in the way that as NPS fertilizer increased, duration of vegetative phase of potato also prolonged and in turn maturity date delayed. Bosland and Votava (2012) indicated that, N is critical for pepper growth, but too much N can overstimulate vegetative growth, thus it results in large and succulent late maturing plants. Akram, *et al*. (2017) revealed that control/unfertilized experimental units prolonged pod maturity and turning to red color; while the shortest fruit ripening duration was recorded at P_{100} K_{120} kg ha^{-1} which was non-significant with P_{150} K_{120} kg ha^{-1} with 60.33 and 60.67 number of days, respectively.

4.2. Yield components and Yield

4.2.1. Number of pods plant

Number of pods $plant^{-1}$ was significantly ($p<0.05$) affected by interaction of fertilizer rate (NPSZn + urea) and cultivars. This character was also highly significantly ($P<0.01$) affected by main effect of cultivars and NPSZn + urea rates (Appendix Table 3). The highest average number of pods $plant^{-1}$ (43.47) was recorded when Melka Shote interacted with 84.5 NPSZn +136.5 urea kg ha^{-1}. It is statistically at par with combination of Melka Shote cultivar with 65 NPSZn + 105 urea kg ha^{-1}, 45.5 NPSZn + 73.5 urea kg ha^{-1}, Melka Awaze with 84.5 NPSZn +136.5 urea kg ha^{-1} and Melka Shote with 104 NPSZn + 168 urea kg ha^{-1} with corresponding pod numbers of 41.53, 39.4, 36.4 and 35.1. While, the lowest number of pods $plant^{-1}$ (23.77) recorded from the interaction of Melka Awaze with control (0 kg ha^{-1}) which had no significant variation when the same cultivar combined with 104NPSZn + 168 urea kg ha^{-1}, Melka Shote combined with the control and 26 NPSZn + 42.8 urea kg ha^{-1} with pod number of 27.67, 24.6 and 33.1, respectively (Table 6).

Regardless of the quantity of pod numbers, NPSZn + urea positively increased pod number plant^{-1} in both cultivars up to a certain level. This might be due to the contribution of each nutrient in NPSZn fertilizer for balancing the growth of vegetative (root, stem and branches) and reproductive parts at the optimum rate. Beyond this level, NPSZn + urea enhance vegetative growth at the expense of reproductive growth. Thus, reduce pod number plant^{-1} and yield per unit area. N enhances rapid growth, increases leaf size and promotes fruit and seed development (Tucker, 1999). Evidently, N is an integral constituent of many essential plant compounds like chlorophyll, proteins and a major part of all amino acids Brady and Weil (2002); thus, it contributes positively for yield increments. Zinc in the plant increases cell differentiation; the greater the cell differentiates the larger and denser the number of fruit plant^{-1} (Anonyms, 2002).

In line with this, Tesfaw *et al.* (2013) reported that fruit number plant^{-1} statistically differed due to cultivars, N and P; whereby the highest average number of pods plant^{-1} was obtained from the plots received 92 kg ha^{-1} of N and 138 kg ha^{-1} P_2O_5; but it varies with cultivar. Mebratu *et al*. (2014); Simon and Tesfaye (2014); Ayodele *et al. (*2015); Wahocho *et al*. (2016) found that N rates revealed positive association and highly significant variation on pod number plant^{-1}. Wossen (2017) indicated that number of pods plant^{-1} was highly significantly affected by the application of different levels of blended fertilizer (NPK) containing 23%N, 10%P, 5%K, 3%S, 2%Mg, and 0.3% Zn. As this author reported, the highest pod number plant^{-1} was noted at 92/69 N/P_2O_5 kg ha^{-1}; while the lowest number of pods plant^{-1} was recorded from unfertilized plots.

4.2.2. Marketable dry pod yield

Marketable dry pod yield (t ha^{-1}) was significantly ($p<0.05$) affected by the interaction of fertilizer rates (NPSZn + urea) and cultivars. Similarly, it was highly significantly ($p<0.01$) influenced by main effect of fertilizer rates (NPSZn + urea) and cultivars (Appendix Table 3).

The maximum and significantly different marketable dry pod yield (2.29 tha^{-1}) was noted when Melka Shote cultivar combined with 84.5 NPSZn +136.5 urea kg ha^{-1}. While the lowest (1.28 t ha^{-1}) was recorded when Melka Awaze kept unfertilized (control) (Table 6). This could be strongly linked to yield components like pod length, pod width, higher seed weight and total dry pod weight plant^{-1}.

Deficiency of N resulted in stunted growth, appearances of chlorosis and red and purple spots on the leaves, restrict lateral bud growth (from which leaves, stem and branches develop) (Bianco *et al*., 2015). However, at the optimum rate which varies with cultivar, season and soil, N accelerates photosynthetic processes; leaf area production as well as net assimilation rate (Ahmad *et al.*, 2009) which are determinant of crop yields (Rafiq *et al.*, 2010). Phosphorus is needed for photo-assimilate metabolism, sugar and starch formation, energy transfer and movement of carbohydrates. Thus, it contributes for yield ascending by providing and storing sufficient food for the plants (Hamza, 2008).

Application of S helps the uptake of N, P, K and Zn by the plant and increases crop productivity and quality (Zhang *et al*., 1999). Increasing yield at relatively higher rates of Zn may be due to the contribution of Zn in protein synthesis and energy production, nucleic acid synthesis, carbohydrate and lipid metabolisms which in turn helps to increases the yield and quality of vegetable crops (Hansch and Mendel, 2009). Application of fertilizers containing sufficient Zn increases performance and quality of crops (Alloway, 2008). Activity of RuBP, carboxylase enzyme, Photosystem II, ATP synthesis and chloroplasts activity influenced by Zn. Thus, application of this nutrient helps the growth of hot pepper by encouraging the uptake of P and Fe from the soil which are important particularly for increasing the yield, seed and quality of the vegetable crops (Vitosh *et al*., 1994; Prasd *et al*., 1999).

Generally, different hot pepper cultivars did not perform similarly at the same rate of fertilizer level which might be attributed to inherent characters and adaptability of the cultivars to the area. In accord to this finding, Fekadu and Dandena (2006) suggested that genetic variability and heritability are determinant of pod yield and yield contributing characters of hot pepper. N exerted highly significant difference on marketable yield whereby the highest marketable yield was obtained at 100 kg N ha^{-1} (Mebratu *et al*., 2014). Wahocho *et al*. (2016) reported pods weight plant^{-1} were affected by the interaction effect of cultivars and N level in which the highest weight of pods plant^{-1} observed from the cultivar Ghotki at N level of 250 kg ha^{-1}. However, the cultivar Longi produced minimum pods weight plant^{-1} at nitrogen level of 0 kg ha^{-1}. Plants sprayed with both Zn and B or Zn alone showed maximum pod diameter, pod length and individual fruit weight hot pepper (Sultana *et al*., 2016).

4.2.3. Unmarketable dry pod yield

The interaction of cultivars and fertilizers rates had exerted significant ($p<0.05$) difference on unmarketable dry pod yield. It also influenced highly significantly ($p <0.01$) by the main effect of NPSZn + urea rates (Appendix Table 3). Statistically the highest unmarketable dry pod yield (0.20 t ha^{-1}) was observed by the interaction of Melka Awaze with 0 kg ha^{-1} of NPSZn + urea kg ha^{-1} followed by the interaction of this cultivar with 104 NPSZn + 168 urea (0.19 t ha^{-1}) and Melka Shote with 84.5 NPSZn +136.5 urea kg ha^{-1} (0.15 t ha^{-1}) (Table 6). In this case, the highest unmarketable yield obtained at the control could be attributed to lack of nutrients leading to weak growth of the plant and smaller pod size. The highest level of NPSZn + urea enhanced vegetative growth (due to N in this rate) which in turn increases unmarketable yield.

Phosphorus is crucial primary macro plant nutrient involved in enhancing flower bud development and seed formation; thus, application of P helps the growth and maturity of fruits and seed (Kelly, 2009). In contrast, lack of phosphorous prolonged maturity and poor seed and fruit development (Uchida, 2000). Zinc also has an important role in pollen production and seed development by activating enzymes used in photosynthesis (synthesis of sufficient photo assimilates). So that zinc deficient plants delayed to mature and increases unmarketable yield by reducing the quality of the fruits (Shukla *et al*., 2009). Shortage of Zn decreased the performance and quality of crop due to decline in plant photosynthesis and destroy RNA, amount of carbohydrates and synthesis of protein (Mousavi *et al*., 2007; Efe and Yarpuz, 2011). Zinc also contributes in auxin metabolism, viable pollen formation and the resistance to infection by certain pathogens which directly contribute for plant growth, pod formation and maturity (Alloway, 2008). To the reverse, it is obvious that lack of this nutrient negatively affects the growth of the plant and yield.

Similarly, excessive N lead to growth of more branches, increased plant height which could have increased competition for assimilate partitioning among the plant parts. This reduces pod length and width and increases unmarketable yield of hot pepper cultivars (Mebratu *et al*., 2014). Ghaffoor *et al*. (2003) reported that unfertilized cultivar gave significant maximum unmarketable yield. Moreover, Nigussi *et al*. (2017) reported the highest unmarketable yield obtained from the control treatment, while the least unmarketable yield was recorded from plots treated with application of 69 kg N ha^{-1}.

4.2.4. Total dry pod yield

Total dry pod yield (marketable and unmarketable yield) was affected significantly ($p<0.05$) by the interaction effect of both factors and by main effect of cultivars. It also highly significantly ($p<0.01$) influenced by the main effect of fertilizer rates (NPSZn + urea) (Appendix Table 3). The highest mean value of total yield ha^{-1} (2.44 t ha^{-1}) was recorded at the interaction of Melka Shote with 84.5 NPSZn +136.5 urea kg ha^{-1} rate. While the lowest total yield ha^{-1} (1.46 t ha^{-1}) was noted when Melka Shote cultivar received no nutrient which is statistically at par with combination of Melka Awaze with 0 NPSZn + urea Kg ha^{-1} (1.48 t ha^{-1}) and 26 NPSZn + 42.8 urea kg ha^{-1} (1.64 kg ha^{-1}) (Table 6). The highest total yield might be attributed to the production of more number of pods having marketable size which is probably the function of supplied nutrients and inherent characters of the cultivars.

Phosphorous promotes a strong stem growth, producing large number of flower and contribute for increasing the number of fruits. Thus, compared with control, the higher concentrations of N, P and K gave significantly more yields per plant (Fandi *et al*., 2010). In similar way, Sainju *et al*. (2003) reported that phosphorous has a positive role in stimulating healthy root growth which helps in better utilization of water and nutrients. In opposite, Zekri and Obreza (2003) stated that lower concentrations of N, P and K limit plant growth, flower and fruit production due to their effects on photosynthesis and carbohydrate synthesis, consequently, yield and marketable fruits will be reduced.

Nitrogen is a constituent of amino acids required to synthesize proteins and other related compounds and plays critical role in almost all plant metabolic processes which are positively associated with plant growth and yield (Tucker, 1999). Because of central role of S and N in the synthesis of proteins, the functions of these nutrients in plants are highly inter-related. S and N relationships were established in many studies in terms of dry matter and yield increment (Jamal, 2010). Application of Zn significantly increased the leaf chlorophyll, sugar and protein concentrations over control and positively influenced the growth and yield of tomato cultivars (Gurmani *et al*., 2012). Furthermore, Gurmani *et al*. (2012) reported tomato cultivar responded better towards Zn application by accumulating greater biochemical and higher antioxidants and ultimately produced yield than the Riogrande as compared to control.

In accord to this, yield and quality of pepper are greatly improved through application of N and P (Baghour *et al*. 2001). Increasing P level increased pod yield of hot pepper cultivar (Simon and Tesfaye, 2014). Tesfaw *et al.* (2013) reported that cultivars treated with 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} produced the highest total dry pod which was statistically not different from the yield produced at 46 N ha^{-1} and 69 P_2O_5 ha^{-1}. Similarly, high phosphorus concentration (100 ppm) in the nutrient solution gave the highest total yield $plant^{-1}$ (Fandi *et al*., 2010). Furthermore, N at a rate of at 100 kg ha^{-1} produced the highest total dry pod yield (3.1 t ha^{-1}) compared to 1.08 t ha^{-1} recorded at the control (Mebratu *et al*., 2014). Yield of snake tomato fruit was higher when treated with 15 and 30 kg P_2O_5 ha^{-1} than those of 30 kg P_2O_5 ha^{-1}, 60 kg ha^{-1} of P_2O_5 and control treatments (Idowu *et al*., 2013). Moreover, maximum yield was produced, when plants treated with 0.05% of Zn in combination with 0.03% of B; while minimum pod yield was produced by untreated plants (Sultana *et al*., 2016).

Table 6. Interaction effect of cultivar with fertilizer rates on days to 50 % flowering, days to first harvest, number of pods plant^{-1}, marketable, unmarketable and total dry pod yield.

Treatment		Phenological, yield components and Yield parameters					
Cultivars	NPSZn/urea (kg ha^{-1})	DT 50%F	DTFH	NPPP	MDPY (t ha^{-1})	UDPY (t ha^{-1})	TDPY (t ha^{-1})
MA	0	87.00^{f}	173.33^{abc}	23.77^{f}	1.28^{f}	0.20^{a}	1.48^{e}
	26/42.8	90.33^{edf}	170.33^{bcd}	33.53^{bcde}	1.50^{ef}	0.13^{c}	1.64^{de}
	45.5/73.5	94.33^{bcd}	159.67^{f}	28.03^{def}	1.85^{bcd}	0.11	1.96^{bc}
	65/105	94.33^{bcd}	162.00^{ef}	31.67^{cdef}	2.02^{b}	0.11^{c}	2.13^{b}
	84.5/136.5	99.33^{a}	167.33^{de}	36.40^{abcd}	1.93^{bc}	0.13^{c}	2.06^{bc}
	.04/168	99.33^{a}	169.00^{cd}	27.67^{def}	1.65^{de}	0.19^{ab}	1.83^{cd}
MS	0	90.33^{def}	177.33^{a}	24.60^{ef}	1.33^{ef}	0.13^{c}	1.46^{e}
	26/42.8	91.33^{def}	166.67^{de}	33.10^{bcdef}	1.73^{cde}	0.12^{c}	1.85^{bcd}
	45.5/73.5	89.00^{ef}	170.00^{bcd}	39.40^{abc}	1.89^{bcd}	0.12^{c}	2.01^{bc}
	65/105	92.33^{cde}	167.00^{de}	41.53^{ab}	1.90^{bcd}	0.13^{c}	2.03^{bc}
	84.5/136.5	97.00^{abc}	173.67^{abc}	43.47^{a}	2.29^{a}	0.15^{abc}	2.44^{a}
	104/168	97.33^{ab}	175.67^{ab}	35.10^{abcd}	1.85^{bcd}	0.14^{bc}	1.99^{bc}
LSD (0.05)		4.72	5.87	9.46	0.27	0.05	0.30
CV (%)		1.49	2.03	9.49	7.69	17.7	7.56

Means within columns for each variable followed by different letters are statistically different from each other at ($p<0.05$).

MA = Melka Awaze, MS = Melka Shote, DT 50%F = Days to fifty percent flowering, DTFH = Days to first harvest, NPPP = Number of pods plant^{-1}, MDPY = Marketable dry pod yield, UDPY = Unmarketable dry pod yield, TDPY = Tot al dry pod yield

4.3. Physical Quality Characters

4.3.1. Pod length and width

Pod length of hot pepper was significantly ($p<0.05$) affected by interaction of cultivars and NPSZn + urea as well by the main effect of NPSZn + urea. However, it was not significantly ($p \geq 0.05$) influenced by cultivars. Pod width was not significantly ($p \geq 0.05$) influenced by all factors (Appendix Table 4). The maximum pod length (10.99) was noted at the interaction effect of Melka Awaze with 65 NPSZn + 105 urea kg ha^{-1}. This is at par with the combination of same cultivar with 45.5 NPSZn + 73.5 urea kg ha^{-1}, Melka Shote with 84.5 NPSZn + 136.5 urea kg ha^{-1}, 26 NPSZn + 42.8 urea kg ha^{-1} and with 45.5 NPSZn + 73.5 urea kg ha^{-1} with average pod length of 10.7, 10.4, 10.1 and 9.97 cm respectively. While the shortest pod length (8.1 cm) was obtained when Melka Awaze cultivar interacted with the control fertilizer (Table 7). These might be attributed to the function of cultivar and applied nutrients.

Different literature revealed that auxin is involved in the regulation of fruit growth and development as it is produced or mobilized from storage in pollen and contribute for pod growth and even after fertilization, fruit growth may depend on auxin from developing seeds. Application of Zn and B or Zn alone increased pod diameter, pod height compared with unfertilized crop (Sultana *et al*., 2016).

In line with this, increasing N to 100 kg ha^{-1} resulted in the highest pod length. But further increase from 100 to 150 kg N ha^{-1} decreased pod length as it favors the growth of vegetative plant parts (Mebratu *et al*., 2014). Similarly, application of 75 kg N ha^{-1} produced the highest pods length (Ayodele *et al*., 2015). $P_{100}K_{120}$ kg ha^{-1} gave longest pod length (9.0 cm); while the shortest fruit length was recorded in the treatment where no fertilizer was applied (control) (Akram *et al*., 2017). El-Bassiony *et al*. (2010) reported that fruit length and fruit weight were increased with increasing plant nutrients particularly P, N and K. Moreover, Shil *et al*. (2013) reported the longest pod length was recorded from application of 3.0 kg Zn ha^{-1}; which was significantly different from the control and the rate above 3.0 kg Zn ha^{-1}.

Table 7 . Interaction effect of cultivar with fertilizer rates on pod length and pod width

Treatment		Pod size	
Cultivars	NPSZn + urea kg ha^{-1})	Pod length (cm)	Pod width (cm)
MA	0	8.1^{f}	1.07^{a}
	26/42.8	8.6^{def}	1.13^{a}
	45.5/73.5	10.7^{ab}	1.1^{a}
	65/105	10.99^{a}	1.2^{a}
	84.5/136.5	8.8^{def}	1.01^{a}
	04/168	8.7^{def}	0.96^{a}
MS	0	8.6^{ef}	1.07^{a}
	26/42.8	10.1^{abcd}	1.3^{a}
	45.5/73.5	9.97^{abcde}	1.3^{a}
	65/105	9.1^{cdef}	1.1^{a}
	4.5/136.5	10.4^{abc}	0.97^{a}
	104/168	9.5^{bcdef}	0.87^{a}
LSD (0.05)		1.5	NS
CV (%)		9.3	20.73

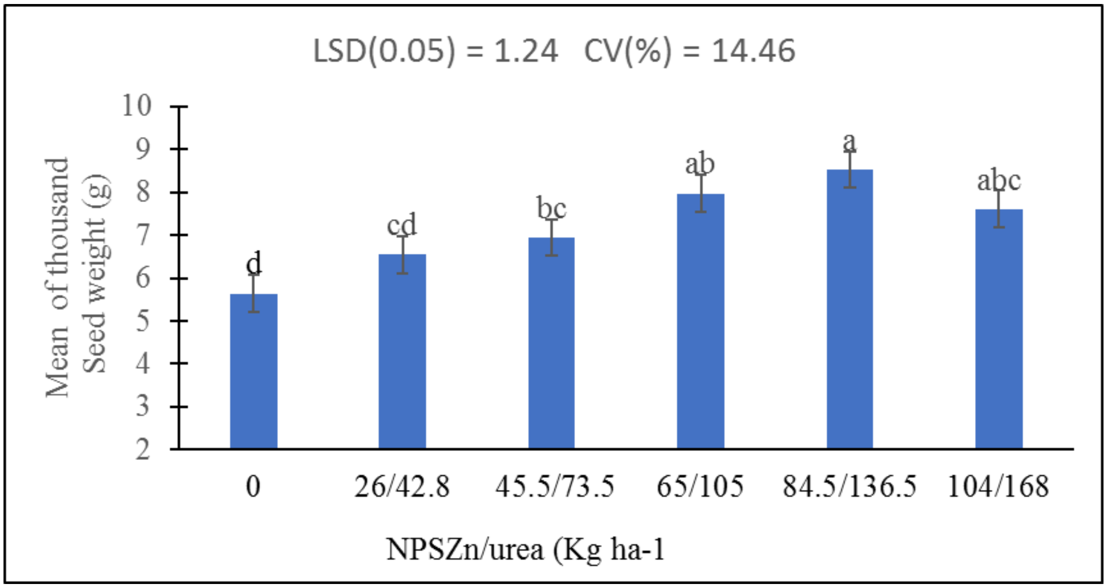
NS = Non-significant at p ≥ 0.05, Means within columns for each variable followed by different letters are statistically different from each other at (*p < 0.05*).

4.3.2. Thousand seed weight

Thousand seed weight had highly significantly (*p < 0.01)* influenced by NPSZn + urea rates, but not statistically significantly affected by cultivars and interaction effect of cultivars and NPSZn + urea rates (Appendix Table 4). Accordingly, the highest (8.52 g) and significantly different thousand seed weight was recorded at 84.5 NPSZn+136.5 urea kg ha^{-1} followed by at 65 NPSZn + 105 urea kg ha^{-1} (7.97 g) and 104 NPSZn + 168 urea kg ha^{-1} (7.62); while the lowest (5.64 g) was recorded at the control (Figure 3).

The highest seed weight recorded at the highest rate of NPSZn + urea might be due to relatively the highest P and N concentration present in NPSZn + urea. Evidently, Tucker (1999) reported P involved in seed germination and early growth, stimulates blooming, enhances bud set and helps seed formation. This author also indicated that N enhances fruit and seed development. Similarly, Beyene and David (2007) reported that the better the fruit setting characteristics of the plant with well-developed larger sized fruit and seed weight are directly related with the amount of nutrients taken from the soil. Thus, the larger and wider hot pepper pods are considered to be the best in quality and have better demand for fresh as well as dry fruit use in Ethiopian markets. Adugna (2008) also reported that application of N and P increased vegetative growth, photosynthetic capacity and better partitioning of assimilate towards the pods which increases the weight of seed pods and yields.

In line with this study, P_{100} K_{120} kg ha^{-1} and P_{200} K_0 kg ha^{-1} attained the maximum weight of seeds; whereas the lowest thousand seed weights were obtained at T_0 (control) and P_{150} K_0 kg ha^{-1} (Akram *et al*., 2017). Singegol *et al.* (2007) investigated that higher P resulting in higher seed yield. Pod length was highly significantly influenced by the application of different levels of blended fertilizer in which the highest pod length was observed by application of 92/69 NP_2O_5 kg ha^{-1} and the lowest by the control (Wossen, 2017).



Means with different letters are statistically different from each other at ($p<0.05$)

Figure 3. Main effect of NPSZn + urea on average value of thousand seed weight

4.4. Soil Chemical Properties Analyzed after Harvesting

Chemical properties of the soil after harvest showed increase in contents of total nitrogen, available phosphorus, organic matter and organic carbon; but decreased in pH as the rates of applied NPSZn + urea increased. But the value also varied with the hot pepper cultivars as they may have different nutrients uptake ability (Table 8).

In comparison of total N after harvest for each treatment with total N before transplanting, the value was decreased after harvest. This might be due to leaching and crop uptake of N from the soil (Kryzanowski, 2005). The concentration of soil available N and P influenced by exploitation of soil nutrients by different species (Zheng *et al*., 2017). Moreover, plant species have varying influence on applied N and P and these can affect the soil nutrient accumulation and loss (Binkley *et al.,* 1992; Lee *et al*., 2012). Nitrogen in the soil can be lost through emissions of ammonia, nitrous oxide and nitric oxides (Adamczyk *et al.*, 2017). Likewise, nitrification and subsequent leaching can be also responsible for soil available N loss (Wang *et al*., 2015) and leading to reduction in total N content of the soil.

Available P after harvest for each treatment also reduced from the primary value. As plants take up phosphate, the concentration of available phosphate could be decreased. This might be also due to the rational that P reacted with elements such as calcium or aluminum and become unavailable and reduces available P (Pagliari *et al*., 2017). Soil P loss is predominately caused by surface runoff. Run off and leaching contribute to the loss of soil P. Due to soil available P consumption (plant uptake), declines in sources of organic P and loss of soil available P mainly in the presence of rain and furrow irrigation reduces soil available phosphorous (Bai *et al.,* 2013). Application of NPKM (Nitrogen, Phosphorous, Potassium and Manure), NPK and NP nutrients increased the available P concentration in the soil in the order of NPKM>NP>NPK (Zhan *et al*., 2015).

Soil pH was often influenced by fertilizations. Elemental sulfur, iron sulfate and aluminum sulfate are products used to acidify the soil in the way that soil bacteria combine elemental sulfur with oxygen and water from the soil to form sulfuric acid (Mickelbart *et al*., 2010). The pH value decreased (Acidity increased) due to application of nitrogen containing fertilizer like urea since it behaves similar to ammonia and H^+ ions produced during the ammonification-nitrification process (Guo *et al*., 2010). McCauley *et al*. (2009) suggested that application of sulfur based fertilizers are used to lower the pH of soils in such a way that elemental sulfur is oxidized by microbes to produce sulfate (SO_4^{2-}) and H^+, resulting a lower pH. Horneck (2011) suggested sulfur containing compound lowers the soil pH.

Table 8. Soil chemical properties analysis result after harvest

No.	Treatments	Value				
		N (%)	P (%)	OC (%)	OM (%)	pH
1	MA (0 NPSZn + urea kg ha^{-1})	0.141	0.0016	1.404	2.420	7.2
2	MA (26 NPSZn + 42.8 urea kg ha^{-1})	0.158	0.0017	1.425	2.457	7.2
3	MA (45.5 NPSZn + 73.5 urea kg ha^{-1})	0.162	0.0017	1.513	2.608	7.2
4	MA (65 NPSZn + 105 urea kg ha^{-1})	0.17	0.0017	1.538	2.652	7.1
5	MA (84.5 NPSZn + 136.5 urea kg ha^{-1})	0.179	0.0018	1.592	2.745	7.1
6	MA (104 NPSZn + 168 urea kg ha^{-1})	0.182	0.0018	1.621	2.795	7.1
7	MS (0 NPSZn + urea kg ha^{-1})	0.152	0.0017	1.502	2.589	7.1
8	MS (26 NPSZn + 42.8 urea kg ha^{-1})	0.157	0.0017	1.539	2.653	7.1
9	MS (45.5 NPSZn + 73.5 urea kg ha^{-1})	0.161	0.0017	1.620	2.793	7.1
10	MS (65 NPSZn + 105 urea kg ha^{-1})	0.163	0.0017	1.661	2.864	7.1
11	MS (84.5 NPSZn + 136.5 urea kg ha^{-1})	0.171	0.0017	1.681	2.898	6.9
12	MS (104 NPSZn + 168 urea kg ha^{-1})	0.176	0.0018	1.71	2.948	6.9

MA = Melka Awaze, MS= Melka Shote

4.5. Correlation

Plant height was highly significantly ($p < 0.01$) and positively associated with days to 50% flowering ($r = 0.54^{**}$), number of pods per plant ($r = 0.48^{**}$), marketable ($r = 0.45^{**}$) and total dry pod yield ($r = 0.49^{**}$). Total leaf area and leaf area index were highly significantly and positively related with days to 50% flowering, number of pods per plant, marketable dry pod yield and total dry pod yield. Both of these characters also positively and significantly ($p<0.05$) associated with thousand seed weight. As total leaf area and leaf area index are the indicators of light interception and photosynthetic rate, they have positive relationship with the yield of the crop. This shows, as leaf area and leaf area index decrease the yield also decreased. Evidently, leaf area and leaf area index are important determinants of light interception and consequently photosynthesis and plant productivity (Goudriaan and Van Laar, 1994). Similarly, Premalakshmi (2001), Hannan *et al.* (2007) and Hayder *et al.* (2007) reported significant positive association between yield and leaves/plant and plant height in tomato.

The canopy diameter of hot pepper cultivars was highly significantly ($p<0.01$) correlated with days to 50 % flowering ($r = 0.75^{**}$), marketable ($r = 0.44^{**}$) and total dry pod yield ($r = 0.48^{**}$). This might be due to the positive relation of canopy with branch number which contributes to highest number of pods per plant. Number of primary branches per plant was highly significantly ($p<0.01$) and positively associated with days to 50% flowering ($r=0.59^{**}$), number of pods per plant ($r=0.59^{**}$), thousand seed weight ($r=0.62^{**}$), marketable ($r = 0.71^{**}$) and total dry pod yield ($r=0.72^{**}$). Secondary branches per plant were significantly ($p<0.05$) and positively correlated with marketable ($r=0.38^{*}$) and total dry pod yield ($r=0.39^{*}$). Similar to leaf area index, canopy spreading has also great role in determining light harvest, photosynthesis and then positively influence the maturity and crop productivity. Both primary and secondary branches of hot pepper are indubitably pod producing plant part. Thus, those characters are positively related with the yield and yield related parameters. In accordance, Premalakshmi (2001); Wedajo (2015) reported significant and positive associations between plant height, number of branches and fruit number plant^{-1} and total fruit yield.

Above ground dry biomass was significantly (*$p<0.05$*) and positively associated with number of pods plant^{-1} (r = 0.39*). It also positively and highly significantly (*$p<0.01$*) correlated with thousand seed weight (r = 0.57**), marketable (r = 0.67**) and total (r = 0.69**) dry pod yield (Table 9). Dry biomass is the reliable growth indicator of the plant; thus, it is the determinant of yield components and yield of the plants. Dry biomass accumulation is an important indicator of crop final product and performance. it also indicates the distribution pattern of assimilation from the source to the sink (Chen *et al*., 2018). In line with this, biomass dry weight showed a strong positive association with number of fruits per plant, fruit weight, yield and negative relationship with fruit width (Martey, 2015).

Number of pods plant^{-1}, pod length, thousand seed weight were positively and significantly correlated with Marketable and total dry pod yield. This might be due to the rational that yield per unit area of hot pepper is the contribution of yield attributing characters like the size and the number of the fruits plant^{-1}. So, the number of fruits plant^{-1}, the size of fruit, marketable and total yield hectare^{-1} are highly and positively correlated. In accord to this, Singh *et al*. (1997); Singh *et al*. (2014); Shumbulo, 2016) reported that number of fruits per plant were positively and significantly correlated with total green fruit yield and dry fruit yield of C*apsicum species*. Wedajo (2015) also reported marketable yield per hectare was significantly and positively correlated with yield parameter. Similarly, fruit length had a significant positive association with yield and seed weight (Martey, 2015).

Table 9. Pearson correlation coefficients analysis results of Growth, Yield components and Yield variables

	PH	TLA	LAI	CD	NPBP	NSBP	AGDB	DTF	DTFH	NPPP	PL	PW	TSWt	MDP	UmDP	TDPY
PH	1	0.61**	0.41*	0.56**	0.48**	0.09^{ns}	0.38*	0.54**	-0.07^{ns}	0.48**	0.16^{ns}	0.21^{ns}	0.14^{ns}	0.45**	0.27^{ns}	0.49**
TLA		1	0.75**	0.56**	0.77**	0.33*	0.57**	0.77**	0.27^{ns}	0.67**	0.11^{ns}	-0.03^{ns}	0.36*	0.60**	0.20^{ns}	0.63**
LAI			1	0.40*	0.69*	0.23^{ns}	0.47**	0.60**	0.21^{ns}	0.60**	0.22^{ns}	-0.18^{ns}	0.42*	0.57**	0.06^{ns}	0.59**
CD				1	0.44**	0.15^{ns}	0.71**	0.75**	-0.20^{ns}	0.33^{ns}	0.09^{ns}	-0.05^{ns}	0.24^{ns}	0.44**	0.31^{ns}	0.48**
NPBP					1	0.45**	0.67**	0.59**	0.10^{ns}	0.59**	0.21^{ns}	-0.09^{ns}	0.62**	0.71**	-0.02^{ns}	0.72**
NSBP						1	0.45**	0.27^{ns}	-0.03^{ns}	0.22^{ns}	0.02^{ns}	-0.15^{ns}	0.32^{ns}	0.38*	0.01^{ns}	0.39*
AGDB							1	0.69**	-0.22^{ns}	0.39*	0.21^{ns}	-0.13^{ns}	0.57**	0.67**	0.11^{ns}	0.69**
DTF								1	-0.04^{ns}	0.42**	0.20^{ns}	-0.16^{ns}	0.26^{ns}	0.53**	0.21^{ns}	0.56**
DTFH									1	0.04^{ns}	-0.35*	-0.12^{ns}	-0.15^{ns}	-0.24^{ns}	0.45**	-0.18^{ns}
NPPP										1	0.29^{ns}	0.14^{ns}	0.32^{ns}	0.67**	-0.01^{ns}	0.68**
PL											1	0.08^{ns}	0.23^{ns}	0.51**	-0.32^{ns}	0.48**
PW												1	-0.25^{ns}	0.12^{ns}	0.04^{ns}	0.12^{ns}
TSWt													1	0.63**	-0.23^{ns}	0.61**
MDP														1	-0.14^{ns}	0.99**
UmDP															1	-0.02^{ns}
TDPY																1

* = Significant at 5 %, ** = Significant at 1 %; PH = Plant height, TLA= Total leaf area, LAI =leaf area index, CD = Canopy diameter, NPBPP = Number of primary branch per plant, NSBPP = Number of secondary branches per plant, Above ground dry biomass, DTF = Days to flowering, DTFH =Days to first harvest, Number of pod per plant, PL = pod length, PW =pod width, TSWt = thousand seed weight, MDPY = Marketable dry pod yield, UmDPY = Unmarketable dry pod yield, TDPY =Total dry pod yield

4.6. Partial Budget Analysis

4.6.1. Net Benefit Analysis

The net benefit was estimated for 12 treatments as illustrated in (Table 10). Net benefit was increased linearly up to a certain level in both cultivars although the total costs that vary were increased as long as the rate of the NPSZn + urea increases. Accordingly, the application of 84.5 NPSZn + 136.5 urea kg ha^{-1} on Melka Shote cultivar had gave the highest net benefit which is 132037 ETB followed by the application of 65 NPSZn + 105 urea kg ha^{-1} on Melka Awaze cultivar which gave net benefit of 108404 ETB. While the lowest net benefit (44027.1 ETB) was obtained when Melka Awaze cultivar kept unfertilized, followed by unfertilized Melka Shote (48527.1 ETB) cultivar.

Application 84.5 NPSZn + 136.5 urea kg ha^{-1} on Melka Shote cultivar which gave net benefit of 132037 ETB was the most profitable treatment and the peak fertilizers rate to apply to this cultivar. While, the second most profitable is the application of 65 NPSZn + 105 urea kg ha^{-1} on Melka Awaze cultivar which gave net benefit of 108404 ETB and the peak NPSZn + urea rate to apply. As the total costs that vary increased over the optimum level, the net benefit achieved above this level is not enough to compensate the cost beyond the cost of optimum rates of NPSZn + urea fertilizers (reduced net benefit or high cost of production and low net benefit).

Table 10. Net benefit return analysis for the application blended fertilizers rates (NPSZn) and urea on hot pepper cultivars.

Treatment	MDPY ($t\ ha^{-1}$)	AY ($t\ ha^{-1}$)	TC (ETB ha^{-1})	GFB (ETB ha^{-1})	NB (ETB ha^{-1})
MA (0 NPSZn + urea kg ha^{-1})	1.28	1.15	71172.93	115200	44027.10
MA (26 NPSZn + 42.8 urea kg ha^{-1})	1.50	1.35	72072.53	135000	62927.50
MA (45.5 NPSZn + 73.5 urea kg ha^{-1})	1.85	1.67	72729.03	166500	93771.00
MA (65 NPSZn + 105 urea kg ha^{-1})	2.02	1.82	73395.93	181800	108404.00
MA (84.5 NPSZn + 136.5 urea kg ha^{-1})	1.93	1.74	74062.83	173700	99637.20D
MA (104 NPSZn + 168 urea kg ha^{-1})	1.65	1.49	74729.73	148500	73770.30D
MS (0 NPSZn + urea kg ha^{-1})	1.33	1.20	71172.93	119700	48527.10
MS (26 NPSZn + 42.8 urea kg ha^{-1})	1.73	1.56	72072.53	155700	83627.50
MS (45.5 NPSZn + 73.5 urea kg ha^{-1})	1.89	1.70	72729.03	170100	97371.00
MS (65 NPSZn + 105 urea kg ha^{-1})	1.90	1.71	73395.93	171000	97604.10
MS (84.5 NPSZn + 136.5 urea kg ha^{-1})	2.29	2.06	74062.83	206100	132037.0
MS (104 NPSZn + 168 urea kg ha^{-1})	1.85	1.67	74729.73	166500	91770.3D

D = Dominant treatment, MA = Melka Awaze, MS = Melka Shote, MDPY = marketable dry pod yield, AY = Adjusted yield, TC = Total cost, GB = Gross benefit, NB = Net benefit
Price of inputs: Hot pepper seed/Kg =300-birr, Urea = 13 birr kg^{-1}, NPSZn = 13.2 birr kg^{-1}, Price of dry pod = 100 birr kg^{-1}, Labor cost = 50 birr for one person day^{-1}.

4.6.2. Dominance analysis and marginal rate of return

The maximum net benefit by application of blended (NPSZn) + urea fertilizer for the production of the crop alone is not reliable to be recommended for the producer. In most cases, farmers or producers prefer the highest profit (low cost and high income). For this reason, it is necessary to find dominated treatment analysis. The purpose of dominance analysis is to simplify subsequent calculations by ignoring dominant treatments (any treatment with net benefits less than or equal to those of a treatment with lower cost) (Boughton *et al*., 1990; CIMMYT, 1988).

The result from dominant analysis showed that the net benefit of treatment five (application of 84.5 NPSZn + 136.5 urea kg ha^{-1} on Melka Awaze cultivar) and the application of 104 NPSZn + 168 urea kg ha^{-1} to both cultivars (Melka Awaze and Melka Shote) were dominated and left to consider for further analysis (Table 11). The net benefit of these treatments was decreased as the total cost increased above undominated treatments; thus, it may not be accepted by the growers.

Relaying on the maximum net benefit by omitting the dominant treatments alone is not enough to recommend the most profitable treatment (technologies) to the farmers rather estimating the marginal rate of return. Marginal rate of return (MRR) is the ratio of marginal net benefit to marginal variable costs expressed in percentage (Boughton *et al*., 1990; CIMMYT, 1988). However, recommending treatment/s based on marginal rate of return alone is not reliable rather than based on the minimum acceptable rate of return. Then treatments having minimum rate of return above or equal to 50% is acceptable in most cases of fertilizer level trial (CIMMYT, 1988).

The most profitable treatment is application of 84.5 NPSZn + 136.5 urea kg ha^{-1} to Melka Shote cultivar gave net benefit of (132037 ETB ha^{-1}) and marginal rate of return above minimum acceptable rate of return, which is 51.63%. The second is application of 45.5 NPSZn + 73.5 urea kg ha^{-1} to Melka Awaze which gave marginal rate of return below the minimum acceptable rate of return. Thus, to obtain optimum economic return from the production of hot pepper at study area, it is recommended to apply 84.5 NPSZn + 136.5 urea kg ha^{-1} to Melka Shote cultivar. In the case when this cultivar is not available it is advisable to use Melka Awaze cultivar in combination with blended fertilizer and urea at the rate of 45.5 NPSZn + 73.5 urea kg ha^{-1}.

Table 11. Dominance analysis and marginal rate of return for the application of blended fertilizers rates (NPSZn) and urea on hot pepper cultivars.

Treatment	TC (ETB ha^{-1})	NB (ETB ha^{-1})	B:C ratio	MRR%	Rank
MA (0 NPSZn + urea kg ha^{-1})	71172.93	44072.10	0.62		
MA (26 NPSZn + 42.8 urea kg ha^{-1})	72072.53	62927.50	0.87	21.01	
MA (45.5 NPSZn + 73.5 urea kg ha^{-1})	72729.03	93771.00	1.29	46.98	2
MA (65 NPSZn + 105 urea kg ha^{-1})	73395.93	108404.00	1.48	21.94	
MA (84.5 NPSZn + 136.5 urea kg ha^{-1})	74062.83	99637.20D	1.35		
MA (104 NPSZn + 168 urea kg ha^{-1})	74729.73	73770.30D	0.99		
MS (0 NPSZn + urea kg ha^{-1})	71172.93	48527.10	0.68		
MS (26 NPSZn + 42.8 urea kg ha^{-1})	72072.53	83627.50	1.16	10.96	
MS (45.5 NPSZn + 73.5 urea kg ha^{-1})	72729.03	97371.00	1.34	20.95	
MS (65 NPSZn + 105 urea kg ha^{-1})	73395.93	97604.10	1.33	0.35	
MS (84.5 NPSZn + 136.5 urea kg ha^{-1})	74062.83	132037.00	1.78	51.60	1
MS (104 NPSZn + 168 urea kg ha^{-1})	74729.73	91770.30D	1.23		

MA = Melka Awaze, MS= Melka Shote, D=dominated treatments; TVC=Total variable cost; NB=Net benefit; B:C ratio=Benefit cost ratio; MRR% = marginal rate of return, MRR = change in net income / change in cost x 100

5. SUMMARY AND CONCLUSIONS

Hot pepper (*Capsicum annuum* L.*)* is the most widely cultivated and economically important crop. Shortage of information on agronomic practices particularly the right fertilizer rate with respective cultivars across location and season is one of the major productivity limiting issue. Thus, the study was initiated to evaluate the effect of different rates of NPSZn + urea on growth and yield of hot pepper cultivars in Raya Azebo district at Mehoni Agricultural Research study site. Generally, the experiment consisted of two cultivars and five different levels of NPSZn + urea and one without fertilizer application (control) and arranged in Factorial (2 X 6) combination in Randomized Complete Block Design.

Accordingly, plant height, days to first harvest, total leaf area, leaf area index, number of pods plant^{-1}, dry pod yield (marketable, unmarketable and total) and pod length were significantly ($p<0.05$) influenced by interaction of cultivars and NPSZn + urea. Also, days to 50% flowering, number of primary and secondary branches were highly significantly ($p<0.01$) influenced by interaction of cultivars and NPSZn + urea, main effect of cultivars and NPSZn + urea respectively. The main effect of cultivars and NPSZn + urea exerted highly significant ($p<0.01$) and significant ($p<0.05$) difference on canopy diameter, respectively.

The longest plant height (61.27 cm) and the widest canopy diameter (59.63 cm) were recorded from the combination of Melka Awaze with 104NPSZn + 168 urea kg ha^{-1} fertilizer rates. Furthermore, the maximum leaf area index (5.57) and total leaf area (9184.4 cm^{2}) was recorded when Melka Shote was combined with 104 NPSZn + 168 urea kg ha^{-1}. The maximum above ground total dry biomass (121.13 g) was observed at the interaction of Melka Shote with 84.5 NPSZn + urea kg ha^{-1}. Melka Shote cultivar produced the highest (11.71) number of primary branches plant^{-1}. The maximum number of secondary branches (12.10) plant^{-1} and thousand seed weight (8.52 g) were recorded at fertilizer rate of 84.5 NPSZn + 136.5 urea kg ha^{-1}. The interaction of Melka Awaze cultivar with 104 NPSZn + 168 urea kg ha^{-1} and 84.5 NPSZn + 136.5 urea kg ha^{-1} prolonged day to 50% flowering (both 99.33 days). The interaction of Melka Shote with the control delayed days to first harvest (177.33 days). The highest average number of pods plant^{-1} (43.47) was observed at interaction of Melka Shote cultivar with 84.5 NPSZn + 136.5 urea kg ha^{-1}. The longest pod length (10.99 cm) was noted at the combination of Melka Awaze with 65 NPSZn + 105 urea kg ha^{-1}. The highest marketable (2.29 t ha^{-1}) and total dry pod yield (2.44 t ha^{-1}) were recorded when Melkashote is combined with 84.5 NPSZn +136.5 urea Kg ha^{-1}. Also, Melka Shote cultivar at 84.5 NPSZn + 136.5 urea Kg ha^{-1} to also gave the highest net benefit (132037 ETB ha^{-1}) and marginal rate of return above acceptable minimum rate of return (51.63%.).

The overall experiment indicated, the growth characters, phenological and yield of Melka Shote and Melka Awaze cultivars significantly influenced by blended fertilizer (NPSZn) + urea rates whereby the highest marketable dry pod yield (2.29 t ha^{-1}) and the most economically profitable yield was recorded when Melka Shote combined with 84.5 NPSZn +136.5 urea kg ha^{-1}. So, to achieve maximum yield and profitable economic return, growers can use the Melka Shote cultivar with 84.5 NPSZn +136.5 urea Kg ha^{-1} of these fertilizers. In the case when this cultivar is not available it is possible to use Melka Awaze cultivar with 65 NPSZn + 105 urea Kg ha^{-1} of fertilizer which gave total dry pod yield of 2.13 t ha^{-1}.

Thus, at Mehoni agricultural research site and for the surrounding farmers in Raya Azebo and other areas which have similar agro-ecological conditions, application of 84.5 NPSZn + 136.5 urea kg ha^{-1} to Melka Shote cultivar is tentatively recommended to obtain maximum economic return. However, to give sound recommendation it is important to repeat the experiment at this location in different season.

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APPENDICES

Appendix Table 1. Mean square value of plant height, total leaf area, above ground total dry weight, canopy diameter and number of primary branches per plant

Source of Variations	DF	Mean square of Growth and Phenological Components					
		PH	TLA	LAI	AGTDB	CD	NPBPP
Block	2	386.48**	9559930.95**	0.97^{ns}	22.94 ^{ns}	130.3**	43.54**
Cultivars	1	220.02**	4654015.20*	3.25**	237.16 ^{ns}	123.21**	28.80**
Fertilizer	5	185.03**	16478328.45**	3.69**	1609.31**	136.51**	3.25^{ns}
Cult.*Fertilizer	5	74.6*	1934259.34*	1.12*	166.12*	52.83*	2.52^{ns}
Error	22	21.38	673521.0	0.32	60.78	15.06	2.71

* =Significant at (*p<0.05*), ** = highly significant at (*p<0.01*) and

ns = non-significant (*p≥0.05*), DF = Degree freedom, PH = Plant height, TLA = Total leaf area, LAI = Leaf area index, AGTDB = Above ground total dry biomass, CD = Canopy diameter, NPBPP = Number of primary branches plant^{-1}

Appendix Table 2. Mean square value of number of secondary branch plant-1, days to 50% flowering and days to first harvest

Source of Variations	DF	Mean square of growth and Phenological characters		
		NSBPP	DT50%F	DTFH
Replication	2	7.94*	72.69**	16.33^{ns}
Cultivars	1	0.1^{ns}	14.69*	205.44**
Fertilizer	5	8.93**	93.76**	108.8**
Cult * Fertilizer	5	1.30^{ns}	13.09**	32.64*
Error	22	1.85	1.93	11.76

* =Significant at (*p<0.05*) ** = highly significant at (*p<0.01*),

ns = non-significant at (*p≥0.05*), Cult. = Cultivars, DF = Degree freedom, NSBPP = Number of secondary branches plant $^{-1}$, DT50%F = Days to fifty percent flowering, DTFH = Days to first harvest

Appendix Table 3. Mean square values of number of pods per plant, marketable dry pod yield, unmarketable dry pod yield and total dry pod yield

Source of Variations	DF	Mean square of Yield and yield Components			
		NPPP	MDPY	UmDPY	TDPY
Block	2	269.21**	0.10*	0.01**	0.15**
Cultivars	1	325.21**	0.15**	0.001^{ns}	0.12*
Fertilizer	5	170.20**	0.48**	0.003**	0.45**
Cult * Fertilizer	5	34.60*	0.04*	0.002*	0.05*
Error	22	9.93	0.02	0.0006	0.02

* =Significant at *(p<0.05)* ** = highly significant at *(p<0.01)*,

ns = non-significant, at (*p≥0.05*), Cult.= Cultivars, df = Degree freedom, NPPP = number of pods plant^{-1}, MDPY = Marketable dry pod yield,

UmDPY = Unmarketable dry pod yield, TDPY = Total dry pod yield

Appendix Table 4. Mean square value of pod length, width and thousand seed weight

Source of Variations	Degree freedom	Mean square of Physical pod quality		
		Pod length	Pod width	Thousand seed weight
Replication	2	0.88^{ns}	0.14*	1.49^{ns}
Cultivars	1	0.75^{ns}	0.003^{ns}	4.27^{ns}
Fertilizer	5	2.93*	0.06^{ns}	6.49^{**}
Cult * Fertilizer	5	2.69*	0.02^{ns}	1.77^{ns}
Error		0.77	0.05	1.08

* =Significant at *(p<0.05)*

** = highly significant at *(p<0.01)* and

ns = non-significant at (*p≥0.05*) Cult.= Cultivars