EFFECTS OF UREA FERTILIZER AND CHICKEN MANURE ON YIELD AND POSTHARVEST CHARACTERISTICS OF TOMATO (*Lycopersicon esculentum* L.)

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The thesis attached hereto, entitled **"Effects of Urea Fertilizer and Chicken Manure on Yield and Postharvest Characteristics of Tomato (*Lycopersicon esculentum* L.)"** was prepared and submitted by Zar Zar Win under the direction of the chairperson of the candidate's supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of requirements for the degree of **Master of Agricultural Science (Horticulture).**

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DECLARATION OF ORGINALITY

This thesis represents the original work of the author, expect where otherwise stated; it has not been submitted previously for a degree or any other University.

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DEDICATED TO MY BELOVED PARENTS,

U NYO KYI AND DAW NAN SHWE

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ABSTRACT

The study was carried out to assess the effects of urea fertilizer and chicken manure on fruit yield and postharvest characteristics of tomato by using Yezin-2 tomato variety. Experiments were carried out in winter seasons of 2009 and 2010 at Department of Horticulture and Agricultural Biotechnology, Yezin Agricultural University (YAU). Randomized complete block (RCB) design was laid out with four replications. Treatments were control (non-treated), chicken manure (CM) (8 t ha^{-1}), urea fertilizer (100 kg N ha^{-1}) and the rest three treatments were different rates of nitrogen (25, 50 and 75 kg N ha^{-1}) combined with CM. The field data were collected such as plant height (cm), number of branches per plant, number of trusses per plant, fruit setting (%), number of fruits per plant, fruit weight per plant (kg) and total yield (t ha^{-1}). The postharvest studies were assigned into RCB design with three replications. Weight loss (%), firmness (kg cm^{-2}) and total soluble solid (Brix %) of tomato fruits were recorded at four day intervals.

There was significant different in truss number, fruit setting (%), fruit weight, fruit number and total yield (t ha^{-1}) among the treatments in both experiments. The all treated plants with CM showed higher fruit number, fruit weight and total yield than other treatments in the first experiment. The plants treated with the combination of 50 kg N ha^{-1} and CM gave the highest in fruit number, fruit weight and total yield among the treatments in the second experiment. The fruit number, fruit weight and total yield were significantly lowest in control plants in both experiments. Therefore, the combination of urea fertilizer and CM was more effective in most of the growth parameters of tomato than plants treated with N alone and CM alone. It is suggested that the combination of lower amount of urea fertilizer (25 kg N ha^{-1}) and CM should be applied for commercial tomato production for the highest total yield.

Among the treatments, there was significant difference in total titratable acidity (TTA %) at the time of harvest. Breaker stage tomato was lower in TTA % than mature green one. No postharvest characteristics of the Yezin-2 tomato variety were affected by the treatments of urea fertilizer and CM along the storage period. The lower value in weight loss and higher value in firmness were observed in mature green stage tomato than the breaker stage. According to these results, the mature green stage should be harvested for the long storage.

Key words- Tomato, urea fertilizer, chicken manure, yield and postharvest characteristics

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CHAPTER I

INTRODUCTION

Tomato is the native of South America and Mexico (Jahannssen 1979). Tomato (*Lycopersicon esculentum* Mill.) belongs to family Solanaceae. It is the second most widely grown vegetable crop in the world other than potato (Hanson *et al*. 2001a).

Tomatoes are consumed in many ways: the fresh fruits are eaten in salads, sandwiches and as salsa and the processed varieties are consumed dried or as pastes, preserves, sauces, soups and juices (Villareal 1980). Tomato is becoming an important kitchen vegetable in the tropic including Myanmar.

Tomatoes are especially important for the human diet because of their content of vitamin C, carotenes, lycopene and phenolic compounds (Davey and Van Montagu 2000). Tomatoes are a great vegetable loaded with a variety of vital nutrition. It is an excellent source of vitamin C, vitamin A and vitamin K. They are also a very good source of molybdenum, potassium, manganese, dietary fiber, chromium and vitamin B_1. In addition, tomatoes are a good source of vitamin B_6, folate, copper, niacin, vitamin B_2, magnesium, iron, pantothenic acid, phosphorus, vitamin E and protein. Nutritional profile includes carbohydrates, sugar, soluble and insoluble fiber, sodium, vitamins, minerals, fatty acids, aminoacids and more (http://whfoods.org).

The tomato crop is economically attractive due to its good yielding capacity in a short duration (Bagal *et al*. 1989). It is one of the major horticultural crops with an estimated global production of over 4.5 million ha with the yield of about 150 million metric ton (FAO 2012). People's Republic of China has a total annual production of 33,911,702 ton of tomatoes and ranks first in the world tomato production. In Asia, the total tomato production was about 140 million metric ton (FAO 2013). In Myanmar, tomato is grown on about 44,675 ha and its production was about 2 to 3.3 million metric ton (SLRD 2013).

Tomato is a heavy feeder (Upendra *et al*. 2000). So, fertilizer application is essential for good yield of tomato. Tomato plants should be fertilized with organic and/or chemical fertilizers to produce high yield (Hanson *et al*. 2001b). Nitrogen (N) and potassium (K) have a key role in the plant growth and development and it is better to apply the nutrients during the growing stage of the crop and especially phosphorous is needed after transplanting the tomato plant (Arya *et al*. 1999).

The amount of N required by the plants is comparatively larger than other elements (Marschner 1995). N is not only essential for plants growth and development but also it plays an important role in the biosynthesis of fruit constituents (Upendra *et al*. 2000). N mainly affects vegetative growth and fruit yield more than the other nutrients. It promotes the set of flowers and fruits but delay maturity and increase fruit size (Ba- Yosaf 1977). N deficiency results in stunted growth of the plant, which leads to premature flowering and short growth cycle. Moreover, it decreases the total solid in juice and increase titratable acidity (Uexkull 1978).

The effect of excess N may include flower dropping, increased susceptibility to diseases and a deterioration of keeping quality (FAO 1988). An excess of nitrogen causes luxuriant vegetative growth but retards production and decreases fruit quality. Too much N has however been reported to affect the postharvest qualities of tomato fruits (Upendra *et al*. 2000). Parisi *et al.* (2006) reported the nitrogen rate, 250 kg ha^{-1}, increases unmarketable fruit yield. However, Nongkas (1995) reported an increase in the brix and firmness of tomato with a decrease in nitrogen rates.

The use of inorganic fertilizer has not been helpful in intensive agriculture because it is often associated with reduced crop yield, soil acidity and nutrient imbalance (Agbede *et al*. 2008, Ano and Agwu 2005, and Ojeniyi 2000). By adding organic manures, soil enhances microbial activity and increases their ability to conserve fertigation and consequently increasing their fertility and fertilizer use efficiency (Nanwai *et al*. 1998).

Organic fertilizers are very important for providing the plants with their nutritional requirements with the lowest or no soil and ground water pollution (Fawzy *et al*. 2007 and Glala *et al.* 2010).The use of organic fertilizers results in higher growth, yield and quality of crops. They contain macro nutrients, essential micro nutrients, many vitamins, growth promoting factors like IAA, GA and beneficial microorganisms (Natarajan 2007 and Sreenivasa *et al*. 2010).

The application of chicken manure might have increased the release of micronutrients as well as macronutrients in the soil resulting in the better extraction of nutrients, which in turn increases the dry matter production, plant height, number of branches, nutrients uptake leading to higher yield (Dosani *et al.* 1999 and Ramesh 1997). The improvement of fruit quality in tomato due to the application by poultry manure was recorded (Prabakaran and Jamespitchai 2002). Moreover, the shelf life of tomato fruit was also improved due to the application of organic fertilizer (Prabakaran 2003).

Large quantities of organic wastes such as chicken manure and cow dung are easily available and an effective source of nutrients for vegetables such as tomato (Adediran *et al*. 2003a). Awad *et al*. (2002) stated that organic manure contains high levels of relatively available nutrients elements, which are essentially required for plant growth. Organic fertilizer such as cow dung and chicken waste are as a good source of plant nutrients particularly N, P, K, S and judicious application of these along with inorganic nutrients might be helpful to obtain a good economic return as well as to improve soil structure and to maintain soil declining (Solaiman and Rabbani 2006).

For sustainable agricultural development, integrated use of organic manures and chemical fertilizers is effective as an approach for crop production (Sharman 2003). In addition to positive impact of manure, fertilizers are important in biological and physico-chemical soil characteristics and less environmental pollution (Roe *et al.* 1997). Lauer (1975) stated that the use of animal manures supplied 42% nitrogen, 29% phosphorus and 57% potassium of plants.

High and sustained crop yield can be obtained with judicious and balanced NPK fertilization combined with organic matter amendment (Osundare 2004). The combined application of pig manure and nitrogen, phosphorus and potassium (NPK) fertilizer also increased tomato fruit yield compared with pig manure or NPK fertilizer treatments alone (Giwa 2004). Also, Adeniyan and Ojeniyi (2005) found that integrated application of poultry manure and NPK fertilizer increased maize yield compared with poultry manure or fertilizer applications alone.

Postharvest qualities of tomatoes partly depend upon preharvest factors such as cultural practices, genetic and environmental conditions (Hobson 1988). Cultural practices such as nutrient, water supply and harvesting methods of tomato before and after harvest. Many postharvest losses are direct results of factors before harvest (Watkins and Pritts 2001).

The tomato fruit can be harvested at different maturity stages depending upon the market demand. Maturity stage at harvest is a very determinant factor for postharvest quality attributes of tomato fruit such as soluble solid, sugar content, acidity, pH, colour and firmness both in fresh market and processed tomatoes. Quality and duration of shelf life of fruits and vegetables are affected by the combined effect of preharvest and postharvest treatments (Melkamu *et al.* 2008). Fully ripe tomato has only 2-6 days storage life at ambient temperature (FAO 1989). Kader (1992) estimated a postharvest loss of tomato to be about 20-50% in developing countries. There are a number of preharvest and postharvest factors such as handling, harvesting and storage methods, which affect fruit quality and quantity (Melkamu *et al.* 2008).

Therefore, reduction of postharvest losses is so important to recover part of grower's costs. Suitable harvesting stage of fruit (maturity) and optimum ripening conditions to have the best quality and longer storage of tomato have not completely been recognized. And, the increase in yield of tomato due to some of preharvest treatments needs to be necessarily accompanied by the use of appropriate techniques that minimize postharvest loss (Melkamu *et al.* 2008).

In Myanmar, there is a limited literature in tomato production by using nitrogen and chicken manure on yield and postharvest characteristics of tomato. Therefore, the experiment was carried out with these objectives.

Objectives

1. To evaluate the effects of urea fertilizer and chicken manure on growth and fruit yield of tomato
2. To observe the postharvest characteristics of tomato as affected by urea fertilizer and chicken manure

CHAPTER II
LITERATURE REVIEW

2.1. Effects of Chemical Fertilizer on Growth and Yield of Tomato Production

Tomatoes require nutrients such as N, P, K, Mg, Ca, Na and S for good production. These nutrients are specific in function and must be supplied to the plant at the right time and in the right quantity (Shukla and Naik 1993). Although chemical fertilizers have been claimed as the most important contributor to the increase in world agricultural productivity over the past decades (Smil 2001), the negative effects of chemical fertilizer on soil and environment limit its usage in sustainable agricultural systems (Peyvast *et al*. 2008).

Chemical fertilizer also reduces the protein content of crops, and the carbohydrate quality of tomato crops also gets degraded (Marzouk and Kassem 2011). Vegetables and fruits grown on chemically overfertilized soils are also more prone to attacks by insects and disease (Karungi *et al*. 2006).

2.1.1. Nitrogen fertilizer

Nitrogen (N) is the most limiting nutrient to crop production (Pionke *et al*. 1990). The amount of N required by the plants is comparatively larger than other elements (Marschner, 1995). N is also a constituent of a large number of important compounds found in living cells, such as enzymes, amino acids and nucleic acids (RNA and DNA) (Lea and Leegood 1993). The N composition of plant tissue has important nutritional consequences, since plants are a major source of proteins in human diet (Below 1995).

N plays a key role in chlorophyll production and protein synthesis. To achieve the improved N management it is necessary to supply it according to crop need. Similarly, timing of fertilizer application and appropriate source are also necessary for improved N management (Hochmuth *et al.* 1987). This nutrient promotes plant organs development and results in abundant chlorophyll except root growth, which is relatively poor (Lincoln and Edvardo 2006).

N deficiency can seriously decrease yield and crop quality. When N is deficient in plants, plants develop yellow or pale leaves and plant growth is stunted (Mikkelsen 2005). N deficiency results in stunted growth of the plant, which leads to premature flower and short growth cycle. Limiting N reduces fruit set but in excess, vegetative growth is stimulated at the expense of reproduction (Sainju *et al*. 2003).

Mehla *et al*. (2000) and Pandey *et al*. (1996) reported that fruit yield in tomato is highly influenced by the N and phosphorus (P) fertilizer rates applied. Similarly, Sharma *et al*. (1999) also reported average fruit weight of tomato to have been influenced by the amount of NP fertilizers rates applied. Thus, tomato plant should receive optimum amount of NP fertilizers to produce higher fruit yields. According to Hamid (1985), the total N (kg ha^{-1}) required to achieve a target fruit yield is estimated by multiplying by 2.4 the target yield in tons per hectare.

2.1.2. Phosphorus fertilizer

Phosphorus (P) is a vital component of adenosine triphosphate (ATP), which supplies the energy for many processes in the plant. P rarely produces spectacular growth responses, but is fundamental to the successful development of all crops. Modern tomato cultivars and hybrids exhibit high relative growth rates and therefore rely on an adequate supply of P for optimal development and high yields. Indeed, as reported by de Groot *et al.* (2002), the relative growth rate of tomato increases sharply with increasing plant P concentration when the latter is below the critical level of adequacy. It have been reported that foliar application of P in greenhouse tomato enhances the concentrations of chlorophyll, K, P, Mg and Fe in the leaves, accelerates fruit maturity and increases marketable yield and quality (Chapagain and Wiesman 2004). At mild P limitation the assimilate supply is not the limiting factor for reduced growth rates, but at severe P limitation the rate of photosynthesis is depressed, as indicated by the decrease in starch accumulation (de Groot *et al.* 2001). Under conditions of severe P deficiency, the leaf N concentration is also suppressed, due to a decrease in leaf cytokinin levels (de Groot *et al.* 2002).

2.1.3. Potassium fertilizer

Potassium (K) is needed virtually by all crops and often in higher rates than nitrogen. K regulates the plant’s water content and the expansion. It is key to achieving good yield and quality in cotton and critical for increasing the size, juice content and sweetness of fruit. Several studies have directly or indirectly examined the effect of plant nutrition on tomatoes. Of the mineral nutrients, K by influencing the free acid content and P due to its buffering capacity, directly affects tomato quality. K and P nutrition has a positive effect on fruit sugar and acid content (Mikkelsen 2005). Excess K content on chemically over-fertilized soil decreases Vitamin C, carotene content and antioxidant compounds in vegetables (Toor *et al*. 2006).

2.2. Effects of Organic Manure on Growth and Yield of Tomato

The continuous use of chemical fertilization leads to deterioration of soil characteristics and fertility, and may lead to the accumulation of heavy metals in plant tissues which compromises fruit nutrition value and edible quality (Shimbo *et al*. 2001). Organic fertilizers, which mainly come from agricultural waste residues such as cow manure and spent mushroom compost or municipal solid waste compost (MSWC), are often identified as suitable local organic fertilizers. Moreover, it plays an important role for improving soil physical properties. Sustainability in agro-ecosystem involves environmentally friendly techniques based on biological and non-chemical methods (Bonato and Ridray 2007). Among the factors contributing to the low fruit yield of tomato are depletion of soil fertility, soil acidity and nutrient imbalance, arising from continuous use of chemical fertilizers (Obi and Akinsola 1995) and high cost and scarcity of fertilizers (Adediran *et al*. 2003a). These problems can be tackled by adequate application of animal manures, such as those of poultry, cattle, pig and goat which pose disposal problems and environmental hazards on accumulation (Adediran *et al*. 2003a).

2.2.1. Types of organic manure and their nutritional constituents

There are different types of organic manure: chicken manure, cow dung, horse dung, farm yard manure, green manure, compost, vermicompost, rice hulls, groundnut husks, etc.

The effects of organic manure depend on its source which is different in its characteristics such as C/ N ratio and available macro and micro nutrients (Mizur and Wojtas 1984). The crop yield response to organic waste is highly variable and depends on the types of wastes, crop type and species, soil type and climate conditions (Adediran *et al*. 2003a).

Poultry manure is rich in elements of N, P, calcium (Ca), magnesium (Mg), sodium (Na), sulfur (S) and micronutrients including zinc (Zn), copper (Cu) and manganese (Mn). Furthermore, chicken manure is preferred amongst other animal wastes because of its high concentration of macro-nutrients (Warman 1986 and Duncan 2005). For example, Chescheir *et al*. (1986) found nitrogen levels increased 40 - 60% and 17 - 38% in manure added Norfolk sandy soils and Cecil sandy loam soils, respectively.

Organic wastes contain varying amounts of water, mineral nutrients, organic matter (Edwards and Daniel 1992, and Brady and Weil 1996). Awad *et al.* (2002) stated that organic manure contains high levels of relatively available nutrients elements, which are essentially required for plant growth.

Chemical Composition of Poultry Manure	
Property	**Value**
pH	6.8
Organic carbon (%)	14.9
Nitrogen (%)	2.23
C:N	6.7
Phosphorus (%)	0.83
Potassium (%)	2.35
Calcium (%)	1.42
Magnesium (%)	0.58

(Source- Adekiya and Agbede 2009)

2.2.2. Decomposition processes of organic manure

Adesodun *et al*. (2005) demonstrated that application of poultry manure increased soil organic matter, nitrogen, phosphorus, and soil structural stability. Microbial decomposition of poultry manure increases soil temperature, root expansion and consequently uptake of nutrient elements (Chen and Avnimelech 1986). However, the apparent deficiency of an adequate supply of plant-available N from organic fertilizer, resulting from a slow rate of mineralization, makes crop yields in fields treated with organic fertilizer lower than in those treated with chemical fertilizers (Blatt 1991 and Lee 2010). On the other hand, organic fertilizers decompose slowly and nutrients are available for longer period of time, which helps to maintain soil nutrient status (Islam *et al.* 2013). In addition, application of chicken manure to soil enhances concentration of water soluble salts in soil. Nileemas and Sreenivasa (2011) stated that application of liquid organic manure promotes biological activity in soil and enhance nutrients availability to tomato crop.

2.2.3. Effects of organic manure on growth and yield of tomato

Adediran *et al*. (2003a) stated that application of poultry manure increased root system, nutrient uptake, number of sub branch, plant height and tomato fruit yield. Adediran *et al.* (2003b) compared poultry manure, household, market and farm waste and found that poultry manure at 20 t ha^{-1} had highest nutrient contents and mostly increased yield of tomato and soil macro and micronutrients content. Akande and Adediran (2004) found that 5 t ha^{-1} of poultry manure significantly increased tomato and dry matter yield, soil pH, N, P, K, Ca and Mg and nutrient uptakes.

2.3. Integrated Use of Chemical fertilizer and Organic Manure on Tomato Production

One of the most important principles for making a farm more sustainable is reducing the use of synthetic fertilizers by increasing on-farm nutrient cycling and preventing pests and diseases by building healthy and biologically active soil (Yoshiro 2009). Integrated nutrient management is an advanced concept of modern agriculture. Application of chemical fertilizers provides a good yield but soil properties are badly affected.

Olatunji *et al*. (2012) indicated that pig manure and its combination with NPK fertilizer significantly increased growth and fruit yield of tomato and soil organic matter, P, K and Mg in Savannah zone of Southwest Nigeria.

Organic manure (poultry manure, rice straw), plant hormone and chemical fertilizers play an important role in increasing growth and yield of crops. That is why, it is necessary to adopt integrated nutrient management system through combined application of organic and inorganic fertilizers to boost up the crop growth and yield without affecting soil fertility (Islam *et al.* 2013). Ayeni *et al.* (2009) reported that nutrients from mineral fertilizers enhanced establishment of crops, while those from mineralization of manure promoted yield when both materials were combined.

Qian and Schoenan (2002) reported that high and sustained crop yield could be achieved with a judicious and balanced NPK fertilizer treatment combined with organic manure amendments. Incorporation of poultry manure and phosphorus fertilizer increase phosphorus uptake efficiency and availability (Toor and Bahl 1997). Tomato can also be supplied with a combination of compost and mineral N fertilizers to improve fruit yield (Akanbi *et al*. 2005).

The combination of mineral N fertilizer (30 kg N ha^{-1}) and poultry manure had an interactive effect on flowering and fruit production with a significant increase as compared to single application of either treatment. This may be due to increased N availability to the plants from the organic and inorganic fertilizer combinations (Olaniyi and Ajibola 2008).

2.4. Preharvest Fertilizer and Manure on Postharvest Characteristics of Tomato

Nitrogen, phosphorus and potassium are critical for crop yield. The timing and mode of mineral application, chemical form of the minerals applied, and tomato genotype affect the response to varying mineral concentrations on fruit TSS (Benard *et al*. 2009, Chapagain *et al*. 2003, Sainju *et al*. 2003 and Varis and George 1985).

Some studies pointed to an inverse relationship between soil nitrogen concentrations and fruit total soluble solid (TSS) (Elamin and Al-Wehaibi 2005 and Parisi *et al*. 2006). Cherry tomatoes were treated with ammonium nitrate with concentrations varying from 0 to 9 milli molarity (mM) yield, TSS and titratable acidity (TA) increased (Wang *et al*. 2007). At higher concentrations (18 and 36 mM) yields decreased but, surprisingly, TSS and TA still increased in correlation with nitrate concentration (Wang *et al*. 2007). When nitrate concentrations were reduced from 12 to 4 mM, the levels of fruit sucrose, fructose, and glucose increased. But acids were reduced and there was a surprisingly negligible impact on commercial yield (Benard *et al*. 2009). The results from Wang *et al*. (2007) and Benard *et al*. (2009) differed and might be genotype-specific or related to the specific cultivation regimes used. High N, P, and K fertilizers reduced firmness of canning tomatoes. Garrison *et al*. (1967) observed that adequate (73 kg ha^{-1}) N improved fruit quality by prolonging shelf life, increasing fruit size, colour and taste.

Excess nitrogen (110 kg ha^{-1}) decreased fruit size, keeping quality, colour and taste. Mohammed and Zeineb (1988) indicated that soluble solids contents of fresh tomato fruits were not appreciably affected by nitrogen application. Kirimi *et al*. (2011) stated that the differences in the TSS of tomato are not very high by nitrogen fertilizer application. Garrison *et al*. (1967) indicated that nitrogen tends to decrease the percent total soluble solids in the juice and increases TA. The excess amount of N fertilizer (120 kg ha^{-1}) produced less firm fruits in the study of Kirimi *et al*. (2011).

Research has shown that too much soil nitrogen can reduce the vitamin C content of green leafy vegetables such as swiss chard (Comis 1989). Excess nitrogen may lower fruit sugar content and acidity. In certain situations, leafy green plants may accumulate excess soil nitrogen, leading to high concentrations of nitrates in the harvested greens. Fewer studies have examined the effect of potassium and phosphorus concentrations on total soluble solid (TSS).

Higher soil potassium levels reportedly increased TSS in a variety of tomato cultivars (Benard *et al*. 2009; Sainju *et al.* 2003; Wang *et al.* 2009; Weston and Barth 1997 and Winsor 1979). In others, altering potassium levels caused no change in TSS (Peyvast 2006 and Satti and Lopez 1994) except when used to increase soil (Chapagain *et al*. 2003 and Satti and Alyahyai 1995) or hydroponic (Caretto *et al*. 2008) EC values to create a water deficit in the fruit.

Nongkas (1995) reported an increase in the brix and firmness of tomato with a decrease in nitrogen rates. Heeb *et al.* (2005) found that organic sources of nitrogen and ammonium were superior to inorganic nitrate in increasing fruit sugars and acids, which led to better favorable ratings by taste-testing.

2.5. Ripening Physiology of Climateric Fruit

Tomato (*Solanum lycopersicum* L.), being a climacteric fruit, has a relatively short postharvest life since many processes affecting quality loss take place after harvest (Zapata *et al*. 2008). Ripening is a complex process of fruit development, which can be described as a result of biochemical and physiological changes leading to a ripe stage that culminates in dramatic changes in colour, texture, and flavour (Javanmardi and Kubota 2006).

In ripening process of climacteric fruit such as tomato (*Lycopersicon esculentum*), is affected by the rate of ethylene production (Alexander and Grison 2002, and Carrari and Fernie 2006). Upon ripening, ethylene production rate accelerates the severity of changes and reduction of quality (Giovannoni 2001). High CO_2 concentration inhibited ethylene production during tomato ripening (Herner 1987). ‘Fruitiness’ (Bucheli *et al*. 1999) and ‘sweetness’ (Kamal *et al*. 2001) has been identified as two critical contributors to flavor of fresh tomatoes.

The respiratory activity of the tomato can be divided into two parts: pre-climacteric and climacteric. The rate of respiration declines continuously from an initial high, during the first few weeks, to a stage of maturation, especially degradation of starch and changes in the sugar-acid ratio (Beadle 1937, Davies and Cocking 1965 and Winsor *et al*. 1962). Mitochondrial oxidation of succinate, malate, and a-deoxoglutarate becomes enhanced during this period of maturation. A climacteric rise in respiration occurs during ripening (Winsor *et al*. 1962) and is considered a turning point in the life of the fruit in regards to quality. The climacteric maximum may occur either before or after the fruit is removed from the plant, depending upon the harvesting procedures. Mitochondria show reduced rates of oxidation of organic acids at this stage of respiration (Dickinson and Hanson 1965).

2.6. Effects of Maturity Stages on Postharvest Quality of Tomato

Maturity at harvest is very important to composition and quality of tomatoes. The quality is also lost due to biochemical changes which are influenced by growth, maturation, and storage environment. Tomato quality changes continuously after harvesting. During harvesting, tomato fruits ripen and may become overripe quickly depending on their storage temperature and harvest maturity. This can result in loss of quality and restricted shelf life since overripe fruit may be too soft and an unacceptable shade of red (Geeson 1985). The storage performance of tomato fruit depends on cultivars; harvesting stage and storage conditions (Getinet *et al*. 2008). Thus, attempts are being made to decrease postharvest losses and extend storage life by harvesting at physiological maturity and pre cooling (Karki 2005).

Generally, tomato maturity is divided into six stages: green mature stage, breakers stage, turning stage, pink stage, light red stage and red stage based on USDA colour chart (Suslow and Cantwell 2006). Dickinson and Hanson (1965) found that mitochondria isolated from mature green tomatoes were more active than those isolated at other stages. Other factors to consider include the mode of consumption, distance and time to market, and the handling and production system (Cantwell *et al*. 2009, Joas and Léchaudel 2008, Toivonen 2007 and Watkins 2006).

The changes of maturity stage can affect the postharvest performance and fruit quality of tomato (Garcia and Barrett 2005). Goojing *et al.* (1999) reported that 78.2% and 47.5% of rotting can be found in red ripen and mature harvested fruits, after three weeks of storage at 15-20°C, respectively.

Mature green and advanced mature green tomatoes will usually attain a much better flavour at the table ripe stage than those picked at the immature or partially mature stages (Grierson and Kader 1986). The harvesting of tomatoes before they are ripe has an effect not only on the peak sugar content but also on the development of the full flavour spectrum, thus affecting consumer acceptability (Hobson and Grierson 1993). In Florida, most growers harvest tomatoes at the mature green stage (Sherman 1988) because fruit are firmer and ship with less bruising and crushing than fruit harvested at the breaker stage (Kavanagh *et al*. 1986).

The breaker stage occurs after the mature green stage and is distinguished by the development of pale yellow coloration on the blossom end (Karki 2005). Between mature green and red ripe, TSS increases from 2.4% to 5.2% (w/v), with doubling of reducing sugars in some varieties (Cantwell 2000). Therefore, fruits harvested at immature stage reduce sugar import and make the postharvest degradation of starch the primary source of carbohydrates. These two factors are inadequate and undesirable for harvesting (Balibrea *et al*. 2006).

It has been expected that fruits harvested at the later stage would permit greater sugar accumulation than earlier harvested fruits. However, it would be easily damaged and also had short shelf life (Kader *et al*. 1978b, Reid 2002, Toivonen 2007 and Watkins 2006). The accurate maturity indices for each cultivar cannot be overstated (Hertog *et al*. 2004). The popularity of homegrown tomatoes is partly fueled by the ability of consumers to harvest fully-ripened fruit (Rodriguez-Burruezo *et al*. 2005). An essential requirement of industrial postharvest handling is to pick the fruit from mature green to breaker stage to mitigate against some of postharvest losses due to mechanical damage and bruising (Kader and Morris 1978, Kader *et al*. 1978a, b and Reid 2002).

While the harvesting fruit at the red stage is optimal for TSS, the postharvest storage life is limited to a few days (Auerswald *et al*. 1999).

2.7. Postharvest Quality of Tomato

Fruits and vegetables that are infected with pests and diseases, inappropriately irrigated and fertilized, or generally of poor quality before harvesting can never be improved by postharvest treatments (Harvey 1978). The quality of fresh tomatoes is mainly determined by appearance (colour, visual aspects, size, and shape), firmness, flavour and nutritive value.

2.7.1. Fruit colour

Tomato fruit colour is one of the most important and complex attributes of fruit quality. It is the first external characteristic which determines the degree of consumer acceptance. Important colour changes occur at various stages of tomato development in terms of chlorophyll (green colour), β-carotene (orange colour) and lycopene (red colour) contents. The most visible changes are associated with chlorophyll loss and gradual accumulation of lycopene. Transformation of chloroplasts to chromoplasts normally occurs simultaneously with other ripening changes such as cell wall softening (Bathgate *et al*. 1985).

The complexity of tomato colour is due to the presence of a diverse carotenoid pigment system with appearance conditioned by pigment types and concentrations, and it is subject to both genetic and environmental regulation (Arias *et al*. 2000, and Lopez and Gomez 2004). Red colour is the result of chlorophyll degradation as well as synthesis of lycopene and other carotenoids.

2.7.2. Fruit firmness

Firmness is another important quality-related attribute in tomato and may be considered as a final quality index by which the consumer decides to purchase fresh tomato, assessing it by a ‘‘finger test’’ at the time of selection (Batu 1998). Fruit weight loss is affected by several preharvest and postharvest factors, such as harvest date and storage temperature (Alia-Tejacal *et al*. 2007). The major problem concerning tomato firmness is related to tissue softening which usually involves one of two mechanisms: weight loss with turgor loss and a result of enzymatic activity. Weight loss is a non-physiological process associated with postharvest dehydration resulting in turgor loss. Changes in firmness related to enzymatic activity are due to pectinmethylesterase (PME) and polygalacturonase (PG) activity. Enzymatic pectin degradation by PME and PG occurs in two phases: firstly, pectin is partially demethylated by PME resulting in methanol production and in a lower degree of methylation pectin and polygalacturonic acid, and secondly, the latter is depolymerised by PG. PG and PE are the important enzymes involved in fruit softening by solubilizing the polygalacturonic acid in the pectin fraction of the cell walls (Themman *et al.* 1982) during ripening. PG activity increased while firmness decreased with progressive stage of maturation and its synthesis only occurs in response to ethylene (Grierson and Tucker 1983).

The loss of freshness and softening of the tomato tissue is the result of turgor pressure loss and polysaccharides degradation in tomato fruit pericarp (Ealing 1994 and Femenia *et al*. 1998). Initially gradual softening of the tissues and subsequently taste deterioration are characteristic external symptoms which are due to respiratory rate and polysaccharide changes (Chiesa *et al*. 1998, and Van der Valk and Donkers 1994).

2.7.3. Total soluble solid

The major sugar substances that contribute to sweetness are glucose and fructose that play a major role in taste (Stevens *et al*. 1977). Taranov and Krustakalne (1974) found that sugar content varied from 3.9-4.4% in the tomato variety. Sinaga (1986) reported that sugar content increased during maturation from the green mature to the red ripen stage. Salunkhe *et al.* (1974) reported that soluble solids content increases with fruit maturity through biosynthesis process or degradation of polysaccharides. Sugar content varied with the stage of harvesting. Dalal *et al.* (1965) found that reducing sugar (%) were about 2.4% (large green), 2.90% (breaker), 3.10% (pink), 3.45% (red) and 3.65% (red ripen) of fresh weight. Sinaga (1986) reported that sugar content increased during maturation from the green mature to the red ripen stage.

2.7.4. Acidity

Citric and malic acids are organic acids that contribute most to the typical taste of tomato fruit. Other acids such as acetic, formic, trans-aconitic, lactic, fumaric, galacturonic, and a-oxo acids have been detected (Dalal *et al.* 1965, Janes 1941, Rosa 1925 and Winsor *et al.* 1962). Boe *et al*. (1967) observed that the acid content was found to be lower in immature fruit and it was highest at the stages when color appeared with a rapid decrease as the fruit ripened at ambient condition. They also reported that citric acid was the major constituent of total acid and malic acid occurred in small concentration and decrease at the fruit ripened. Winsor *et al.* (1962) found that the maximum acidity can be recorded at the pink stage of tomato fruits.

The sour taste in tomato closely correlates with titratable acidity (Bucheli *et al*. 1999, Malundo *et al*. 1995 and Tandon *et al*. 2003) mainly attributed to citric and malic acids (Petro-Turza 1987). Recently, it has been reported that decline in the acidity level and soluble solid content was associated with quality loss during storage of tomato which can affect consumer’s acceptability (Guillén *et al*. 2006 and Zapata *et al*. 2008). As whole fruit ripens from mature green to red, acidity increases to a maximum value and then decreases (Dalal *et al*. 1965, Janes 194, Rosa 1925 and Winsor *et al*. 1962). Maximum acidity was found at breaker (Winsor *et al*. 1962) and at pink stages (Janes 1941; Rosa 1925; Dalal *et* *al*. 1965). Concentration of acid linearly reduced when temperature increased (Islam *et al.* 1996).

2.7.5. Shelf life

The postharvest loss of tomato was estimated nearly 30-40% through spoilage in developing countries (Akamine 1970). Anju-Kumari *et al.* (1993) reported that the shelf life of all tomato cultivars were longest when harvested at green mature. The main factor associated with tomato postharvest shelf-life, particularly in tropical regions where the temperature is high, is increased respiration which results in faster fruit ripening and deterioration of fruit quality (Bailén *et al*. 2006). Storage life of tomato is limited by several factors including transpiration, postharvest diseases, increased ripening and senescence.

CHAPTER III

MATERIALS AND METHODS

3.1. Yield and Yield Components of Tomato as Affected by Urea Fertilizer and Chicken Manure

3.1.1. Experimental site and periods

The field experiments were conducted for two times at the Department of Horticulture and Agricultural Biotechnology, Yezin Agricultural University (YAU), Nay Pyi Taw. The experimental region is situated at 19˚ 38' N latitude and 96˚ 51' E longitude. The soil type is sandy loam with a pH 5.1. The first experiment was carried out from November 2009 to April 2010. The second one was from December 2010 to May 2011.

3.1.2. Experimental design

Randomized Complete Block (RCB) design with four replications was used for tomato growing experiment. There were different rates of urea fertilizer and/or the combination of chicken manure as mentioned below,

Treatments,

1: Control (non-treated) (Con)

2: Recommended dose of Chicken manure (8 ton ha^{-1}) (CM)

3: Recommended dose of Urea fertilizer (100 kg N ha^{-1}) (N)

4: 25 kg N ha^{-1} and Chicken manure (8 ton ha^{-1}) (25 N+CM)

5: 50 kg N ha^{-1} and Chicken manure (8 ton ha^{-1}) (50 N+CM)

6: 75 kg N ha^{-1} and Chicken manure (8 ton ha^{-1}) (75 N+CM)

All rates of N (25, 50, 75 and 100 kg N ha^{-1}) were adjusted depending on the N concentration of urea fertilizer. Chicken manure was procured from the Yezin area, YAU.

3.1.3. Tested cultivar

The cultivar used in this experiment was Yezin-2 tomato variety from Horticultural Crops Section, Department of Agricultural Research (DAR).

3.1.4. Field procedures, care and management of tomato

After thoroughly land preparation, fertilizers were applied as basal 5 days ahead of transplanting. 25 days old seedlings were transplanted with the spacing of 60 cm between row and 60 cm within plants in each experimental plot size of 3 x 5 m^2. The total experimental area was 360 m^2 occupying totally 24 plots. There were 28 plants per plot and totally 672 plants were grown in the whole experiment.

Urea and chicken manure were used for three times in split application, one for basal application and two for split application. The first side dressing was applied at 25 days after transplanting and the second was done at 40 days after transplanting. The application of Muriate of Potash (100 kg K_2O ha^{-1}) fertilizer was two times for basal and side dressing at 40 days after transplanting. All T-Super (100 kg P_2O_5 ha^{-1}) fertilizer was applied as basal in all treatments.

Watering, weeding and other cultural practices were done as necessary. Furadan was used as basal application to prevent the soil borne diseases problem. Mancozeb, cypermethrin, dimethorax and acephate were applied at weekly interval to control pests and diseases. All these chemicals were applied at recommended rates.

3.1.5. Data collection

Five sample plants were randomly selected from each treatment to collected data. The following growth parameters were weekly recorded. They are plant height (cm), number of branches per plant, number of leaves per main stem till fruit setting. At the time of harvest, plant height (cm), number of branches per plant, number of trusses per plant, fruit setting (%), number of fruits per plant, fruit weight per plant (kg), total yield (t ha^{-1}) were collected.

3.2. Postharvest Study

3.2.1. Experimental site and period

The two experiments were carried out at the Laboratory of Department of Horticulture and Agricultural Biotechnology, YAU. The first experiment was from February to March 2010. The second experiment was from March to April 2011.

3.2.2. Procurement of experimental materials

Breaker stage tomato (81 days after transplanting) and physiologically mature green tomato (70 days after transplanting) were picked in the first experiment and in the second experiment, respectively. Fruits of uniform size, free from any defects and visual defects were selected and stored at room temperature for this study. The fruits were weighted 3 kg for each treatment. After that, the fruits were displayed in bamboo mesh trays as storage container and divided into two groups, non-destructive and destructive sample fruits. Seven sample fruits were used for destructive analysis at one time.

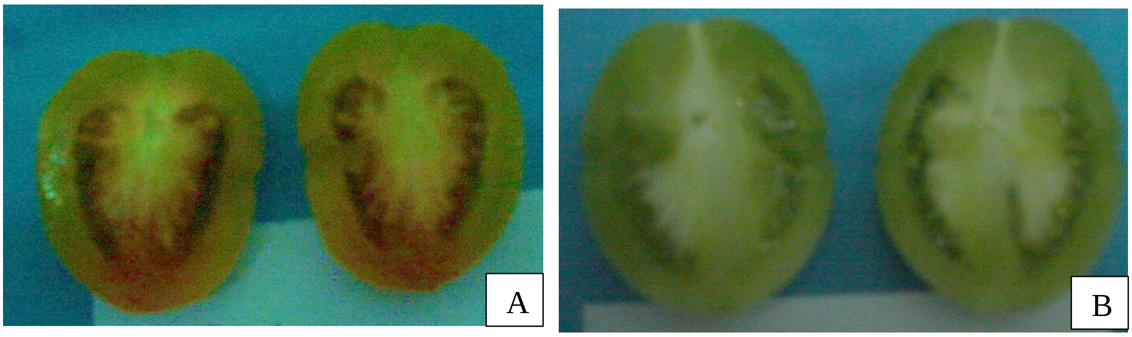

Plate 1. Tomato fruit harvested at (A) breaker stage (25 % orange with 75% green) and (B) mature green stage (100 % green)

3.2.3. Experimental design

The fresh tomato fruits were harvested and used for postharvest storage according to the treatments of field experiments. The harvested fruits were allotted for each container and three containers per treatment were arranged by using RCB design with three replications.

3.2.4. Data collection

The weight loss (%), fruit firmness (kg cm^{-2}) and total soluble solid (TSS) or Brix (%) were recorded at four-day intervals from the beginning to the end of the experiment. All measurements were the same in both experiments.

3.2.4.1. Measurement of weight loss (%)

The weight of sample fruits were recorded at four-day intervals with a digital balance and weight loss of tomato fruit was calculated based on original weight. Percent weight loss was determined by the average weight of 20 sample fruits from each replicate at each sampling date.

3.2.4.2. Measurement of fruit firmness (kg cm^{-2})

Fruit firmness was measured by puncturing the fruit by hardness tester at three places in the equatorial portion with fruit Hardness tester (9300 M-5 kg, Tokyo, Japan).

The maximum force applied is defined as fruit firmness that is measured by the penotrometer guage as mention by Soe 2008.

3.2.4.3. Measurement of total soluble solid (TSS) / Brix (%)

The Total Soluble Solid (TSS) content of tomato fruit pulp was determined by using a pocket refractrometer (PAL- 1) by squeezing the juice from the pulp of tomato fruit. The reading value is expressed as degree Brix (%).

3.2.4.4. Measurement of total titratable acidity (%)

Total titratable acidity (%) of tomato juice was measured by the acid base titration method. The mixture of 10 ml of fruit juice and 90 ml of water was titrated with 0.1 N NaOH using 1-2 drops of phenolphthalene indicator. At the end point, the solution color was changed from colorless to pink color lasting for 30 seconds. Total titratable acidity (%) was expressed as percentage of citric acid. Total titratable acidity was calculated by using the following equation (AOAC 1990).

$$\text{TTA}\ (\%) = \frac{\text{ml NaOH x 0.1 N NaOH x 0.064}}{\text{ml of tomato juice sample}}\ \text{x}\ 100$$

Whereas 0.064 = constant value for citric acid in tomato

3.3. Statistical Analysis

The collected data were statistically analyzed with SAS software programme (version 9.1) and mean comparison was done by using least significant difference (LSD) test at 5% level.

CHAPTER IV

RESULTS

4.1. Yield and Yield Components of Tomato as Affected by Urea Fertilizer and Chicken Manure

4.1.1. Plant height (cm)

Plant height was no significant difference among the treatments in both experiments. Plant height gradually increased up to 3 week after transplanting (WAT) and then increased rapidly at 4 WAT in all treated plants. The plant height was not significantly different among the treatments in both first and second experiments at harvest time (Figure 1, Table 1 and 2).

The plant height ranged from 68.80 cm recorded in the non- treated plants (control), to 77.24 cm recorded in the plants treated with the combination of 25 kg N ha^{-1} and chicken manure. All treated plants were higher than that of non-treated plants in the first experiment (Table 1).

The minimum plant height (57.40 cm) was found in control plants and the maximum plant height (59.23 cm) was recorded in the plants treated with chicken manure in the second experiment (Table 2).

4.1.2. Number of branches per plant

There was not significantly different in number of branches per plant among the treatments. The number of branches per plant increased up to 4 WAT and then remained nearly constant till to the time of harvesting in all treated plants. Thus, there was no significant difference in number of branches per plant among the treatments in both experiments at the time of harvesting. The number of branches per plant ranged from 8.30 to 8.75 in the first experiment and from 5.42 to 6.50 in the second experiment at the time of harvest, respectively (Figure 2, Table.1 and 2).

4.1.3. Number of leaves per main stem

The number of leaves per main stem was not significantly different among the treatments in both experiments. The number of leaves per main stem gradually increased up to 3 WAT and then remained constant till 4 WAT. The number of leaves per main stem ranged from 11 to 12 in both experiments at 4 WAT (Figure 3).

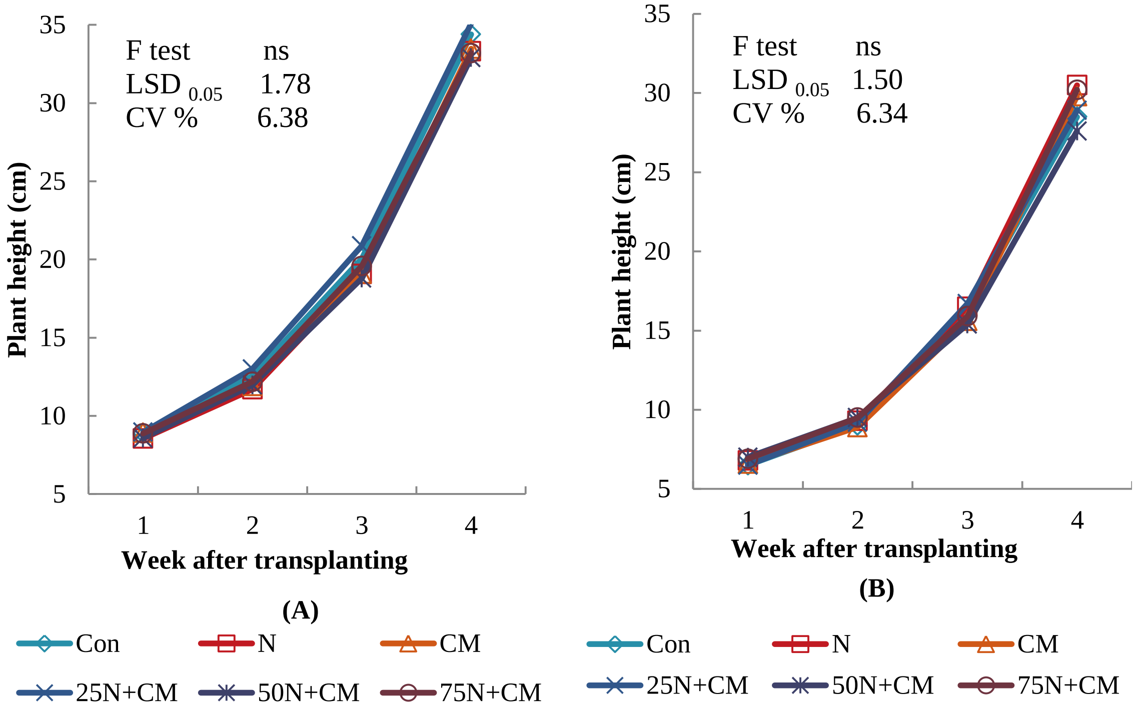

Figure 1. Effects of urea fertilizer and chicken manure on plant height of Yezin-2 tomato variety in (A) 2009 and (B) 2010

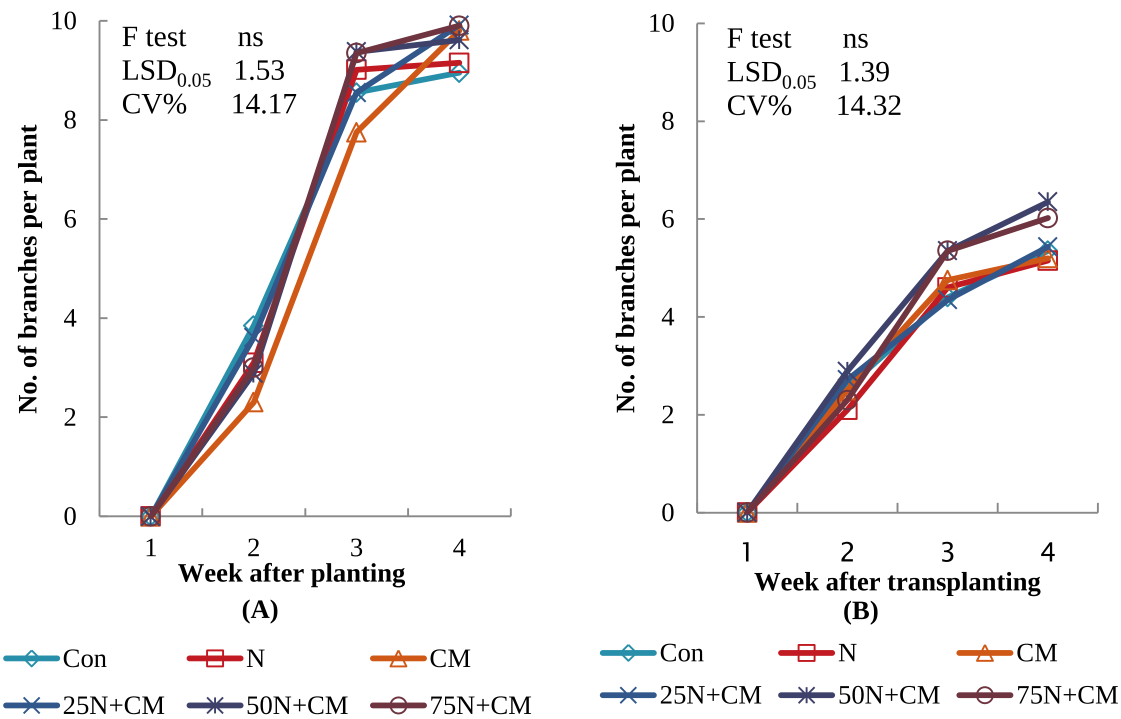

Figure 2. Effects of urea fertilizer and chicken manure on number of branches per plant of Yezin-2 tomato variety in (A) 2009 and (B) 2010

ns- no significant

4.1.4. Number of trusses per plant

The number of trusses per plant was significantly different among the treatments in the first experiment. The maximum number of trusses per plant (27.69) was found in the plants treated with the combination of chicken manure and 50 kg N ha $^{-1}$, however, the minimum number of trusses per plant (16.65) was observed in the non-treated tomato plants. There was found no significantly difference in nitrogen alone- and chicken manure alone- treated plants. However, the plants treated with combination of nitrogen fertilizer and chicken manure gave the higher truss number than that of the control plants, N alone- and chicken manure alone- treated plants (Table 1).

Similarly, there was a significant difference in number of trusses per plant among the treatments in the second experiment. The highest number of trusses per plant (24.65) was found in the plants treated with the combination of 50 kg N ha $^{-1}$ and chicken manure but the lowest number of trusses per plant (14.46) was observed in the control plants. The plants treated with the combination of 50 kg N ha^{-1} and 75 kg N ha^{-1} and chicken manure gained higher number of trusses per plant than those of nitrogen alone- and chicken manure alone- treated plants (Table 2).

4.1.5. Fruit setting (%)

Fruit setting (%) was significantly different among the treatments in both experiments. The plants treated with the combination of 50 kg N ha^{-1} and chicken manure had the highest fruit setting (57.53 %) whereas the lowest fruit setting (39.62 %) was obtained in the non-treated plants. There was not a significant difference in fruit setting (%) in all treatments except the control (Table 1).

The plants treated with the combination of 50 kg N ha^{-1} and chicken manure gave the highest fruit setting (42.65 %) while the lowest fruit setting (20.44%) was observed in the non-treated plants. In comparison with combined use of urea fertilizer and chicken manure, the lowest fruit setting (30.99 %) was obtained in the plants treated with 75 kg N ha^{-1} and chicken manure, however, it was not significantly different from other two combination treatments (Table 2).

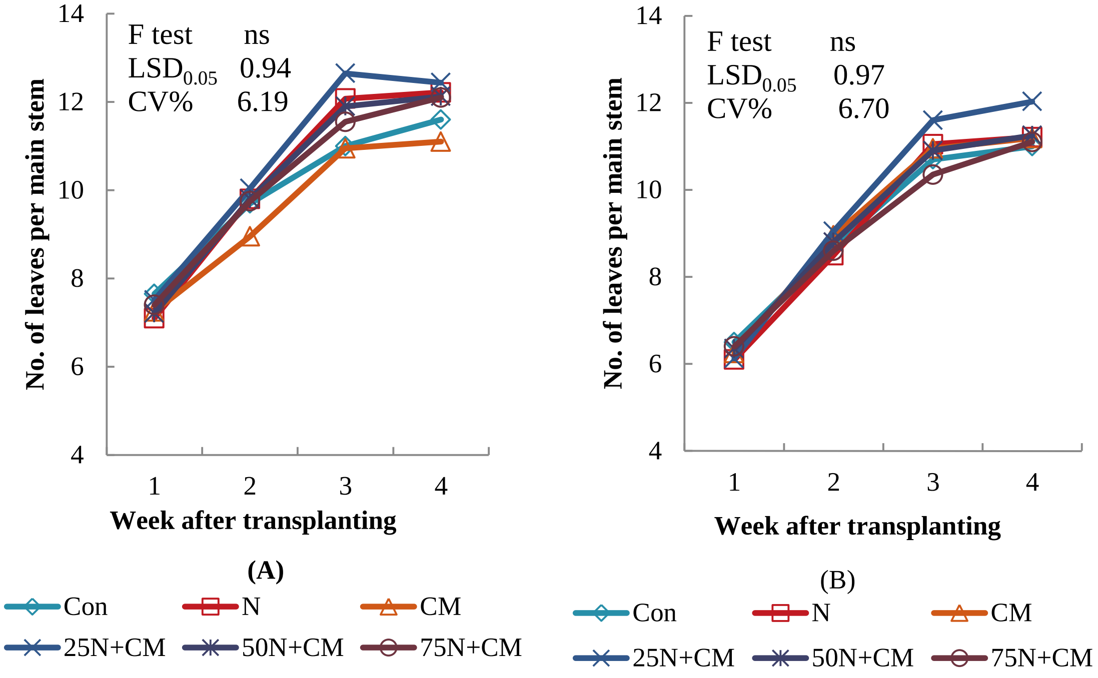

Figure 3. Effects of urea fertilizer and chicken manure on number of leaves per main stem of Yezin-2 tomato variety in (A) 2009 and (B) 2010

ns- no significant

Table 1. Effects of urea fertilizer and chicken manure on yield components of Yezin -2 tomato variety at harvesting time (in 2009)

Treatment	Plant height (cm)	No. branches per plant	No. of trusses per plant	Fruit setting (%)
Control	68.80	8.55	16.65 b	39.62 b
CM	74.80	8.30	23.00 ab	49.20 ab
N	71.30	8.40	19.08 b	47.71 ab
25N + CM	77.24	8.23	26.12 a	52.24 a
50N + CM	73.89	8.32	27.69 a	52.62 a
75N + CM	75.35	8.75	27.08 a	57.53 a
F test	ns	ns	*	*
LSD $_{0.05}$	-	-	6.68	7.15
CV (%)	7.15	9.95	15.11	7.22

Means in the same column followed by the same latters are not significantly different at $P \leq 0.05$

ns-no significant * significant at 5% level

Table 2. Effects of urea fertilizer and chicken manure on yield components of Yezin-2 tomato variety at harvesting time (in 2010)

Treatment	Plant height (cm)	No. of branches per plant	No. of trusses per plant	Fruit setting (%)
Control	57.40	5.50	14.46 b	20.44 b
CM	59.23	5.92	22.41 a	32.41 a
N	57.79	5.42	19.15 ab	33.46 a
25N + CM	58.04	5.83	20.60 a	40.17 a
50N + CM	57.92	6.50	24.65 a	42.65 a
75N + CM	57.63	6.08	23.33 a	30.99 ab
F test	ns	ns	*	*
$LSD_{0.05}$	-	-	5.69	11.45
CV (%)	5.46	12.01	12.50	13.98

Means in the same column followed by the same latters are not significantly different at $P \leq 0.05$

ns- no significant   * significant at 5% level

4.1.6. Number of fruits per plant

There was a highly significant difference in the number of fruits per plant among the treatments in both experiments. The plants treated with the combination of 75 kg N ha^{-1} and chicken manure were the highest fruit number (72.80) which was not significantly different from the plants treated with combination of chicken manure and 25 kg and 50 kg N ha^{-1}. The non-treated plants were significantly lowest in fruit numbers per plant (47.95). There was not significantly different in number of fruits per plant treated with the nitrogen or chicken manure only. However, the plants treated with combination of nitrogen and chicken manure gave the higher in fruit numbers per plant than those from control and nitrogen alone- or chicken manure alone- treated plants (Figure 4).

The highest fruit numbers (44.08) was found in the plants treated with the combination of 50 kg N ha^{-1} and chicken manure. It was followed by only nitrogen treatment (40.00) and the combination of 25 kg N and chicken manure treatment (39.83). The non-treated plants were significantly lowest fruit number (26.58) among the treated plants. There was no significant different in fruit numbers per plants between the treatments with the combination of 75 kg N ha^{-1} and chicken manure, and chicken manure alone (Figure 4).

4.1.7. Fruit weight per plant (kg)

There was a significantly difference in fruit weight per plant of tomato among the treatments in the first experiment. The highest fruit weight per plant (2.4 kg) was obtained from the plants treated with the combination of 25 kg N and chicken manure. However, the lowest fruit weight per plant (1.59 kg) was observed in nitrogen treated plants followed by the non-treated plants (1.64 kg). There was no significant difference among the treatments including chicken manure ranging from 25 kg, 50 kg and 75 kg N ha^{-1} and chicken manure only (Figure 5).

Fruit weight per plant was highly significantly different among the treatments in the second experiment. The highest fruit weight per plant (1.34 kg) was obtained from the plants treated with the combination of 50 kg N and chicken manure, which was not significant different from the plants treated with the combination of 25 kg N and chicken manure. The lowest fruit weight per plant (0.87 kg) was observed from the non-treated plants followed by (0.99 kg) from combination treatment with 75 kg N and chicken manure, and (1.12 kg) from only chicken manure treated plants (Figure 5).

4.1.8. Total fruit yield (ton ha^{-1})

Total fruit yield of tomato was significantly different among the treatments in the first experiment. The significantly highest total yield (36.14 t ha^{-1}) was found in the plants treated with the combination of 25 kg N ha^{-1} and chicken manure and the significantly lowest total yield (23.27 t ha^{-1}) was obtained in the plants treated with urea fertilizer alone. All the plants fertilized by different applications of chicken manure gave a higher total yield than the plants treated from other treatments. Moreover, the yield of plants treated with chicken manure alone was the same as the plants treated with the combination of 25 kg N and chicken manure (Figure 6).

It was found a highly significance in total fruit yield among the treatments in the second experiment. The highest total yield (14.32 t ha^{-1}) of tomato was obtained from the plants treated with the combination of 50 kg N and chicken manure. It was followed by the plants treated with the combination of 25 kg N and chicken manure (13.71 t ha^{-1}). The lowest total yield (9.90 t ha^{-1}) of tomato plant was produced in the non-treated tomato plants followed by 10.53 t ha^{-1} the yield of plants treated with the combination of 75 kg N and chicken manure (Figure 6).

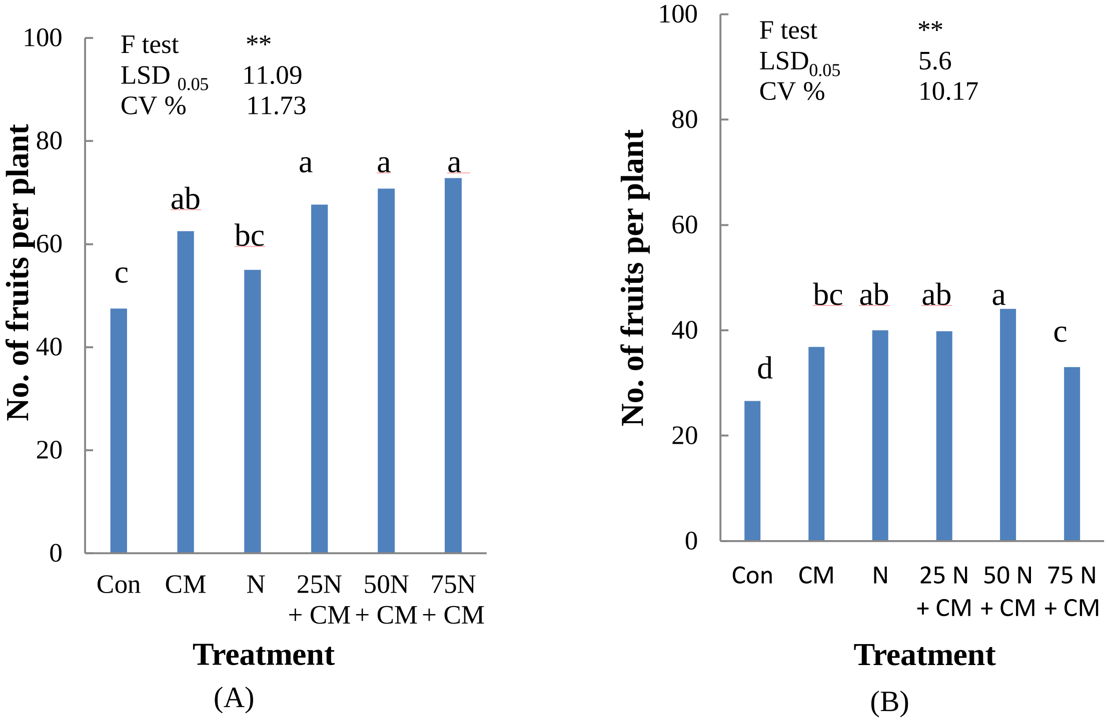

Figure 4. Effects of urea fertilizer and chicken manure on number of fruits per plant of Yezin-2 tomato variety in (A) 2009 and (B) 2010

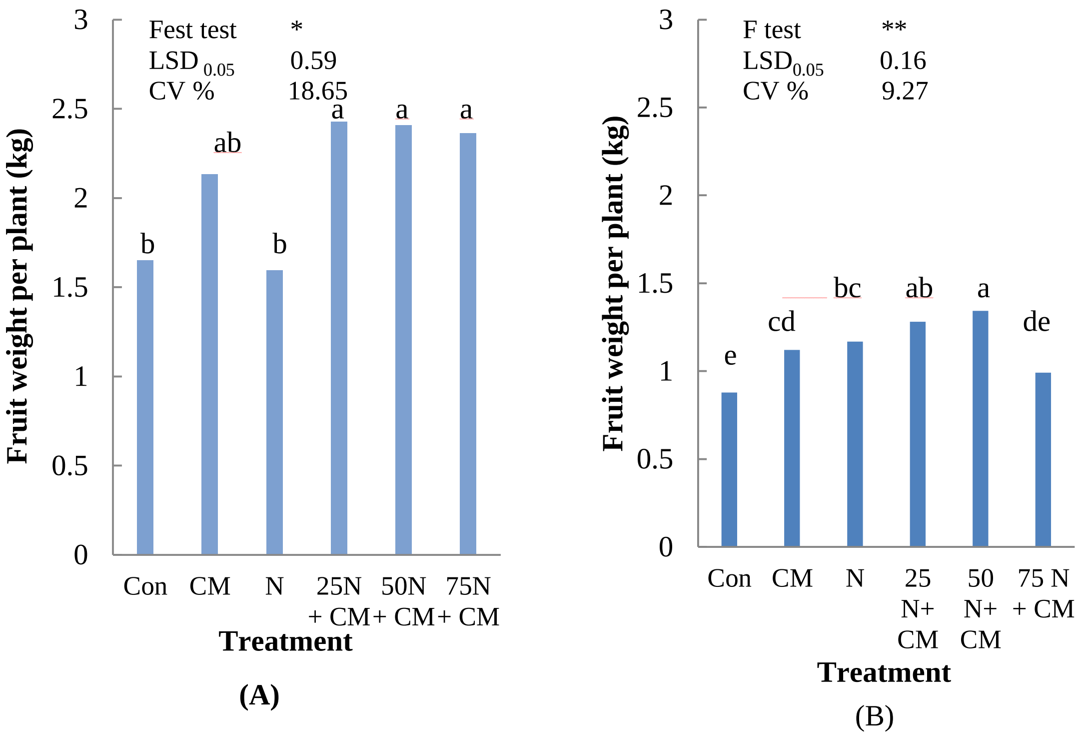

Figure 5. Effects of urea fertilizer and chicken manure on fruit weight of Yezin -2 tomato variety in (A) 2009 and (B) 2010

* significant at 5 % level ** significant at 1 % level

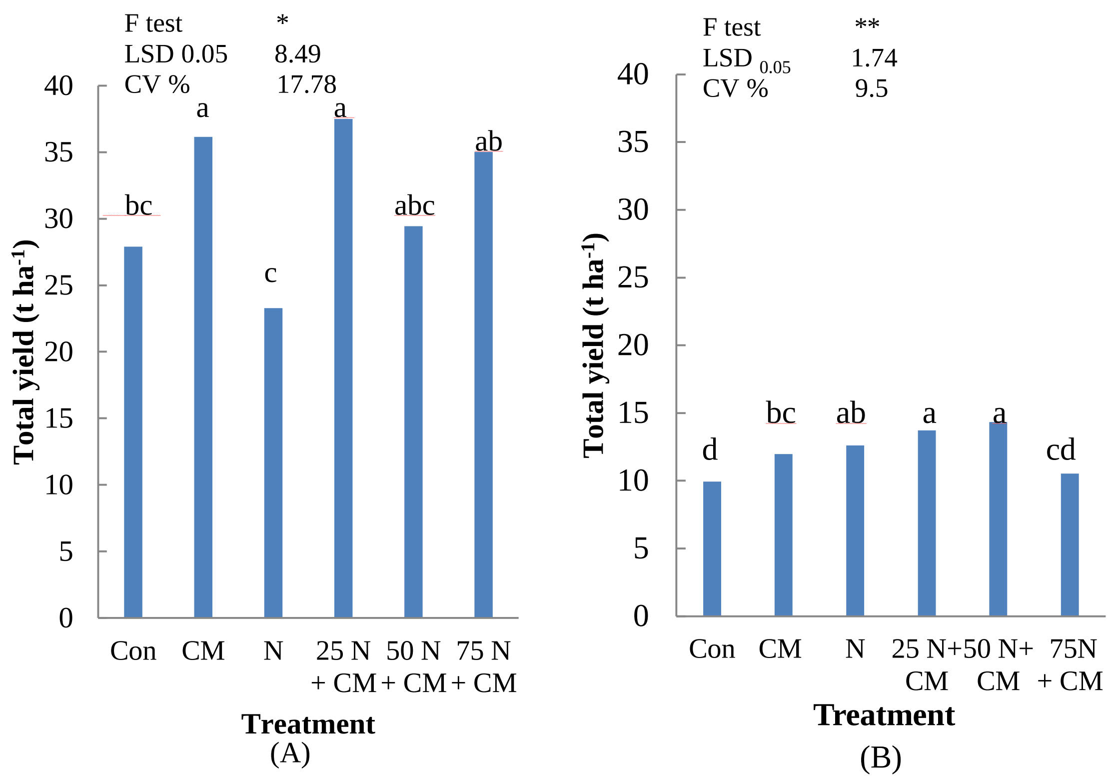

Figure 6. Effects of urea fertilizer and chicken manure on total yield of Yezin-2 tomato variety in (A) 2009 and (B) 2010

* significant at 5 % level ** significant at 1 % level

4.2. Postharvest Characteristics of Tomato

4.2.1. At harvest time

4.2.1.1. Fruit firmness (kg cm^{-2})

In breaker stage, there was no significant difference in fruit firmness among the treatments ranging from 2.72 kg cm^{-2} to 3.23 kg cm^{-2} (Table 3). However, there was significantly different in fruit firmness of green mature stage among the treatments (Table 4).

The highest fruit firmness (3.81 kg cm^{-2}) was found the fruits harvested from the plant treated with the combination of 25 kg N ha^{-1} and chicken manure and the lowest value (3.11 kg cm^{-2}) was observed those fruits of N alone treated plants. But, firmness of fruit recorded in nitrogen alone treated plants was significantly lower than those of fruits from the other treatments. The fruit firmness (3.11 kg cm^{-2}) of mature green fruits harvested from nitrogen alone treated plants was not significantly different those fruits firmness (3.4 kg cm^{-2}) of non-treated plants (Table 4).

The fruit firmness of breaker stage tomato was lower than that of mature green stage tomato in all treatments (Table 3 and 4).

4.2.1.2. Total soluble solid (TSS %) or Brix %

There was a significant difference in total soluble solid (TSS %) of breaker stage tomato among the treatments. The highest total soluble solid (5.37) %) was observed in the fruits harvested from the plants treated with the combination of 75 kg N ha^{-1} and chicken manure and the lowest one (4.32) was obtained the fruits of control plants. The fruits harvested from the plants treated with the combination of 75 kg N ha^{-1} and chicken manure was observed significantly higher in TSS % value than other treatments (Table 3).

The total soluble solid (%) of mature green stage tomato was not significantly different among the treatments ranging from 3.92 to 4.30 (Table 4). The brix of breaker stage tomato was higher than that of mature green stage tomato in all treatments (Table 3 and 4)

4.2.1.3. Total titratable acidity (TTA %)

The total titratable acidity (%) of breaker stage tomato was highly significantly different among the treatments. TTA % of fruits harvested from chicken manure containing treatments gave higher value than those fruits of nitrogen alone treatment and control. The lowest (0.45%) TTA was found the fruits harvested from the plants treated with nitrogen alone and the highest value (0.81%) was obtained the fruits harvested from the chicken manure alone treated plants (Table 3).

There was a significant difference in TTA % of green mature stage tomato among the treatments. The highest TTA % (1.18 %) was found in the fruits harvested from the plants treated with combination of 25 kg N ha^{-1} and chicken manure and the lowest TTA % (0.77 %) was observed in the chicken manure alone treated plants (Table 4).

Table 3. Effects of urea fertilizer and chicken manure on quality of breaker stage tomato at harvest time (2009)

Treatment	Firmness (kg cm^{-2})	Brix (%)	Total titratable acidity (%)
Control	3.23	4.32 b	0.62 b
CM	3.12	4.75 b	0.81 a
N	2.74	4.52 b	0.45 c
25 N + CM	2.51	4.62 b	0.76 a
50 N+ CM	3.00	4.78 b	0.60 b
75 N + CM	2.72	5.37 a	0.62 b
F test	ns	*	**
$LSD_{0.05}$	-	0.466	0.07
CV (%)	9.97	5.39	5.88

Means in the same column followed by the same latters are not significantly different at P ≤ 0.05

ns- no significant * significant at 5% level ** significant at 1% level

Table 4. Effects of urea fertilizer and chicken manure on quality of mature green tomato at harvest time (2010)

Treatment	Firmness (kg cm^{-2})	Brix (%)	Total titratable acidity (%)
Control	3.40 ab	4.30	1.06 b
CM	3.70 a	4.17	0.77 d
N	3.11 b	4.22	0.92 c
25N + CM	3.81 a	4.16	1.18 a
50N + CM	3.65 a	3.92	0.99 bc
75N + CM	3.70 a	4.19	0.95 bc
F test	*	ns	**
LSD0.05	0.396	-	0.12
CV (%)	6.08	3.36	6.49

Means in the same column followed by the same latters are not significantly different at P ≤ 0.05

ns= no significant   * significant at 5% level ** significant at 1% level

4.2.2. During the Storage Period

4.2.2.1. Weight loss (%)

Weight loss (%) in both mature green and breaker stages tomato was not significantly different along the storage period in all treatments. The weight loss of tomato fruits gradually increased in all treatments along the storage period in both maturity stages. The weight loss (%) of mature green stage tomato was higher than that of breaker stage tomato along the storage period (Figure 7).

4.2.2.2. Fruit firmness (kg cm^{-2})

There was a significant difference in fruit firmness of breaker stage tomato among the treatments along the storage period. In both mature green and breaker stages tomato, the highest firmness was at 0 days after storage (DAS) along the storage period. And the fruit firmness of both maturity stages decreased immediately at 4 DAS in all treatments, then, slightly decreased till the end of the storage period. Fruit firmness of mature green stage tomato was not significantly different among the treatments along the storage period (Figure 8).

4.2.2.3. Total soluble solid (TSS %) or Brix (%)

At breaker stage, the brix (%) of the tomato fruits immediately increased at 4 DAS with the value of (5.55 % -5.80 %) in all treatments along the storage period. After that, the Brix (%) of those tomato fruits gradually decreased till the end of the storage period.

The Brix (%) of mature green stage tomato increased during the storage period at 4 DAS and gradually decreased along the storage period in all treatments. The highest Brix % value was observed at 4 DAS with a range between 5.68 % and 5.98 % (Table 5).

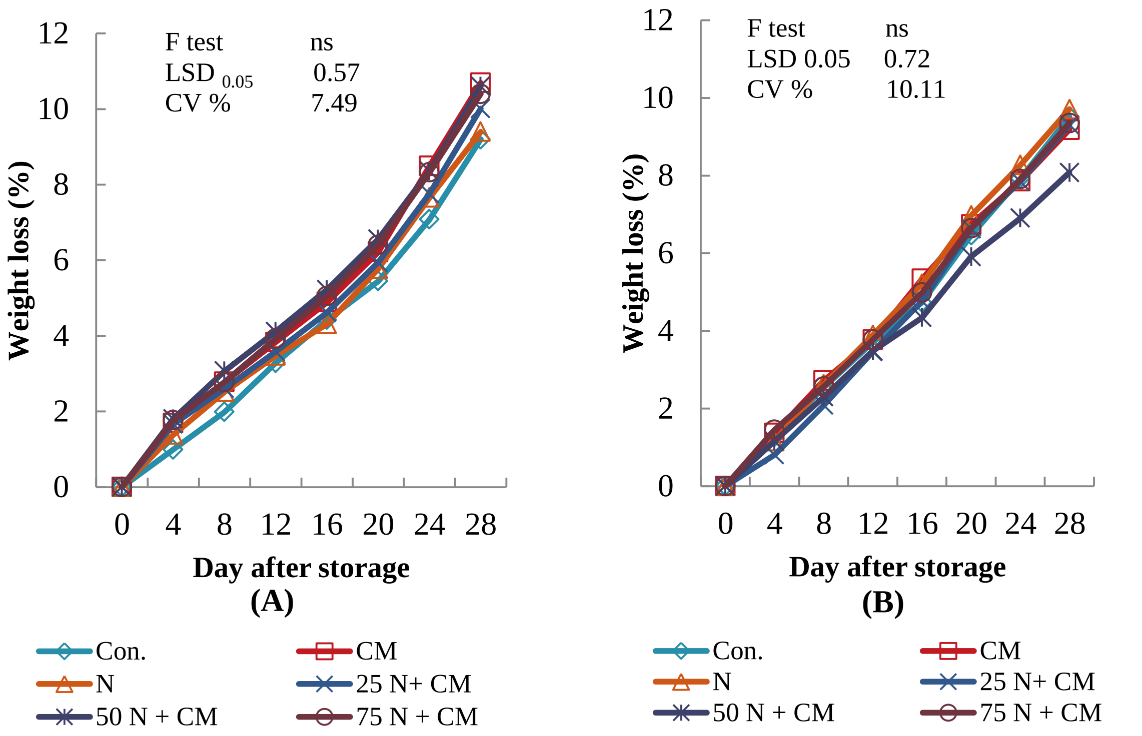

Figure 7. Effects of urea fertilizer and chicken manure on weight loss of (A) breaker stage and (B) mature green stage tomato

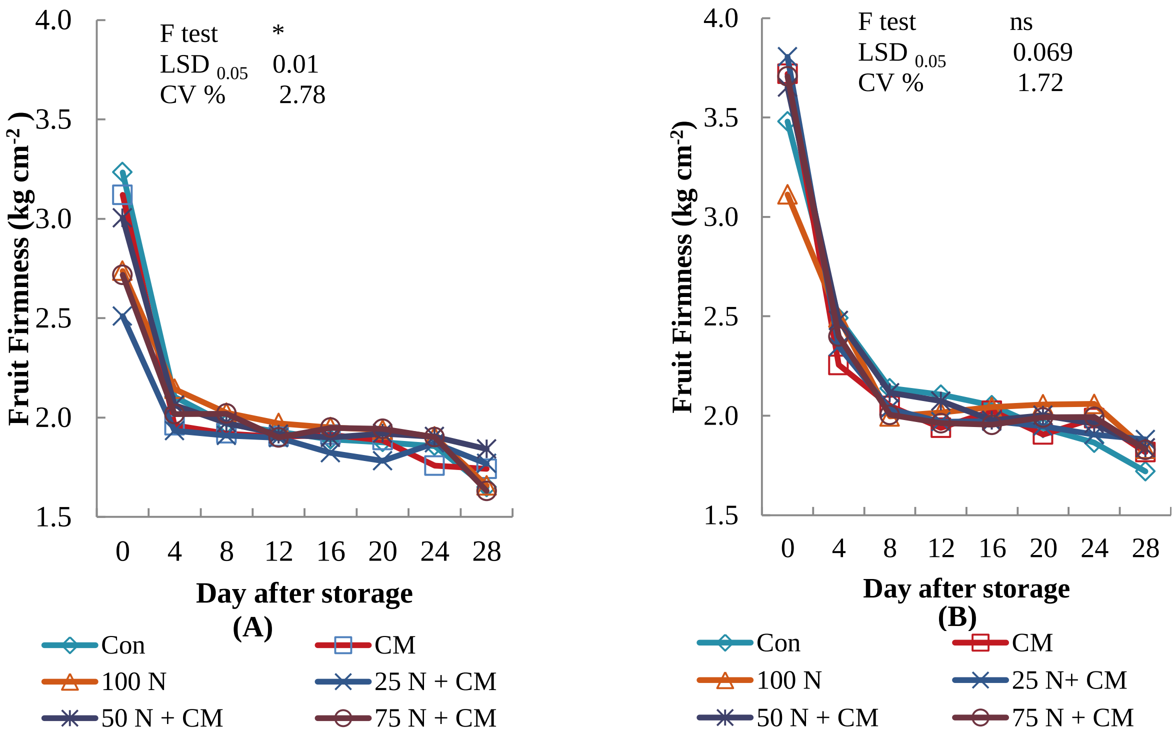

Figure 8. Effects of urea fertilizer and chicken manure on firmness of (A) breaker stage and (B) mature green stage tomato

ns- no significant * significant at 5% level

Table 5. Effects of urea fertilizer and chicken manure on Brix (%) of breaker stage and mature green tomato during storage period

Treatment	Breaker (Brix %) Day after storage					Mature green (Brix %) Day after storage				
	0	4	12	20	28	0	4	12	20	28
Control	4.62 b	5.80	4.71	4.17	3.54	4.30	5.98	5.42	3.71c	3.88
CM	4.75 b	5.55	4.76	4.29	3.79	4.17	5.86	5.38	3.76bc	3.79
N	4.52 b	5.69	4.78	4.17	3.79	4.22	5.88	5.36	4.05a	4.07
25N+ CM	4.42 b	5.75	4.62	4.07	3.95	4.16	5.87	5.22	3.92ab	3.92
50N+ CM	4.78 b	5.61	4.69	4.14	3.86	3.92	5.93	5.44	4.02a	4.07
75N+ CM	5.37 a	5.56	4.79	4.27	3.73	4.19	5.68	5.33	3.76bc	3.84
F test	*	ns	ns	ns	ns	ns	ns	ns	*	Ns
LSD $_{0.05}$	0.466	-	-	-	-	-	-	-	0.19	-
CV (%)	5.39	3.21	2.97	3.77	10.69	3.36	15.5	2.59	2.77	7.77

Means in the same column followed by the same latters are not significantly different at P ≤ 0.05

ns= no significant * significant at 5% level

CHAPTER V

DISCUSSION

5.1. Yield and Yield Components of Tomato

In this study, there was no significant difference in plant height and number of branches per plant among the treatments in both experiments. All treated plants were higher in plant height than control plants in both experiments. These results are similar to the finding of Woldsadik *et al*. (2007), who found that there was no difference in plant height among the manure, ComCat® + manure, ComCat® + NP and ComCat® treatments. This might be due to the ability of manure in creating suitable plant growing environment by improving moisture and nutrient status of the soil. Hader (1986) also reported that the organic fertilizers compensate both the deficit and the excess of elements in the soil, which can take place with mineral fertilization. Similar findings were reported by Hüster (2001). This experiment did not agree with the previous finding of Ibranhim and Fadni (2012), and Ewulo *et al.* (2008), who reported the effect of poultry manure on increasing number of sub-branches in tomato.

The number of trusses per plant and fruit setting (%) was significantly different among the treatments in both experiments. This result is in agreement with the finding of Islam *et al*. (2013), who reported that combined application of organic and inorganic fertilizers had a significant influence (except 15 DAT) on number of flowers per plant. Moreover, they also stated that the highest number of flower clusters per plant was observed in chemical fertilizer with poultry manure and the lowest was recorded in control. The reasons of obtaining comparatively higher flower cluster might be due to the contribution of integrated use of chemical fertilizers and poultry manure (Farhad *et al*. 2009). The present study stated that the plant treated with combination of 75 kg nitrogen ha^{-1} and chicken manure and non-treated plants reduced the fruit setting (%). In support of this study, Sainju *et al.* (2003) reported that excess N fertilizer stimulated vegetative growth but limiting nitrogen reduced the fruit set in tomato. Zekri and Obreza (2003) stated that lower concentrations of N, P and K might limit plant growth, flower and fruit production due to their effects on many aspects of plant growth and development including photosynthesis and carbohydrate production, and consequently, yield and marketable fruits would be reduced.

In this study, integrated use of nitrogen fertilizer and chicken manure gave higher fruit weight, number of fruit per plant and total yield than the plants treated with nitrogen alone and control. Ayeni *et al.* (2010) stated that poultry manure and NPK fertilizers increased number of fruits and fruit weight. Stephenson *et al*. (1990) and Oladotun (2002) reported that poultry manure contains macro and micro nutrients. The number of fruits per plant and fruit weight increased with poultry manure alone and NPK fertilizer plus poultry manure applications (Adekiya and Agbede 2009). The combined application of pig manure and NPK fertilizer also increased tomato fruit yield compared to pig manure alone or NPK fertilizer treatment alone (Giwa 2004). Adekiya and Agbede (2009) found that combined use of NPK fertilizer and poultry manure increased tomato yield compared to application of NPK alone or manure alone. Reza and Jafar (2007) suggested that soil chemical properties were upgraded by integrated use of organic and inorganic fertilizers improving soil organic matter, percentage of organic carbon and total nitrogen. It also reduces soil erosion and improves both nutrient and water retention capacity of the soil. (Vlaming *et al.* 1997).

In the second experiment, the plants treated with the combination of 75 kg N ha^{-1} and chicken manure decreased total yield. Olasantan (1991) also found that fruit yield of the tomato plant was reduced at higher N application rates. It was suggested that there was a nutrient imbalance in tomato with a large increase in N supplied from poultry manure. Excess N in the soil and soil acidity could cause nutrient imbalance in the tomato crop and a reduction in the uptake of certain nutrients. Moreover, the lesser quantities of manure and NPK fertilizer would be reduced expenditure on chemical fertilizer (Ewulo *et al*. 2008).

Yield parameters of tomato plants in the second experiment were lower than those of the first experiment. There are two main reasons for the reduction of yield in the second experiment .The first one is yield reduction could be due to the infection of tomato plants by tomato virus diseases. The continuous growing of same crops in the same field was favorable diseases infection. So the crop rotation should have been done before growing the next tomato crop. The second reason is that tomato plants in the second experiment were encountered with high temperature during the flowering time. The stigma of tomato flowers could be longer than the style due to high temperature. It can reduce the fruit set resulting in decreased yield.

5.2. Postharvest Characteristics of Tomato

Fruit firmness is indicative of level of softening of the fruit that can be affected by maturity stage at harvest time. In this study, fruit firmness of mature green stage tomato was higher than that of breaker stage. Similar result was recorded by Adedeji *et al*. (2006) who reported that firmness of tomato fruit decreased with maturity stage at harvest. And also, the decrease in fruit firmness with advance in maturity stage may be related to the degradation of polysaccharides. According to the results**,** the mature green fruits from the plants treated with chicken manure were firmer than those of nitrogen alone treated plant. Chatterjee *et al*. (2013) stated that increased level of organic manure yielded firmer fruit than fruit harvested from the nitrogen fertilizer treated tomato plants.

There was no significant difference in total soluble solid (%) of Yezin-2 tomato variety at harvest time. These results are similar to those of Krusekopf *et al*. (2002), who found no relationship in soluble solid (SS) as affected by side-dressed chemical fertilizer. Moreover, Herrero *et al*. (2001) stated that soluble solid was not affected by N fertilizer. In this study, total soluble solid (%) of breaker stage tomato was higher than that of mature green stage tomato. In support of this study, Salunkhe *et al.* (1974) reported that soluble solids content increased with fruit maturity through biosynthesis process or degradation of polysaccharides.

The highly significant difference in total titratable acidity (%) of both maturity stages at harvesting time. Breaker stage tomato was lower in total titratable acidity (%) than mature green stage. The results of titratable acidity (%) are contrasted with the finding of Duraisami and Mani (2002), who didn't found appreciable variation in titratable acidity of tomato under different nutrient combinations. Olaniyi and Ajibola (2008) reported that quality components of tomato fruits were affected by environmental conditions, type of manure and genetic characteristics.

The weight loss (%) of tomato gradually increased along the storage period in both maturity stages. This finding is in line with the studies conducted by Kays 1991, who reported that respiration is a central process in living cells that mediates the release of energy through the breakdown of carbon compounds and this gives an indication of the overall metabolism of the plant part which utilizes the plant product as its substrate thereby leading to weight loss. Salunkhe and Desai (1984) also reported that the fruit weight decreased during ripening due to climacteric nature of the fruit that resulted in moisture loss. In both maturity stages, the fruit firmness of tomato was decreased along the storage period. It was observed that the rate of water loss or weight loss increased during ripening that resulted in fruit softness (Lownds *et al*. 1994). The mature green stage tomato gave firmer fruit than breaker stage tomato. Tilahum (2013) reported that firmness notably decreased with advance in maturity stage of tomato fruit.

The TSS % increased to the peak at 4 DAS and then gradually decreased till the end of the storage period. This study agreed with the finding of Workneh *et al.* (2012). They stated that the general trend observed during storage was an initial increase in TSS followed by a decrease. Majidi *et al.* (2011) reported that the TSS content of mature green tomato reached the peak with decreasing trend during storage period. The increase in total sugar content might be due to conversion of starch into sugars (Moneruzzaman *et al*. 2009). Eskin (2000) reported that starch was accumulated in green tomatoes, which started to fall with the onset of ripening. This decrease was accompanied by rising soluble solids. Increase in TSS of tomato fruits could be due to excessive moisture loss which increases TSS concentration as well as the hydrolysis of carbohydrates to soluble sugars (Waskar *et al*. 1999; Nath *et al*. 2011). The TSS content of mature green stage was slowly decreased compare to breaker stage tomato. In support of this finding, Anthon *et al*. (2011) suggested that glucose and fructose concentrations also declined with increasing maturity.

However, further studies were needed to get more comprehensive results for postharvest characteristics of other tomato varieties by the effect of preharvest fertilizer treatment and/or different maturity stages.

CHAPTER VI

CONCLUSION

This study revealed that the integrated use of urea fertilizer and chicken manure could significantly influence fruit number and fruit weight of tomato. The plants treated with the combination of urea fertilizer and chicken manure gave higher total yield than nitrogen alone and chicken manure alone treated plants. Among the combination of urea fertilizer and chicken manure treated plants, the lesser amount of nitrogen (25 kg N ha^{-1}) gave the better yield. In comparison of chicken manure alone and urea fertilizer alone, the plants treated with the former gave the results in same growth parameters of number of trusses per plant, fruit setting per plant, number of fruits per plant and fruit weight per plant. Therefore, chicken manure alone might be used for tomato crop production.

The postharvest characteristics of Yezin-2 tomato variety were no significantly different by the integrated use of urea fertilizer and chicken manure for both maturity stages at the end of the storage period.

The postharvest characteristics of Yezin-2 tomato variety were not different in fruit firmness and brix (%) but lower value in weight loss of the fruits harvested at mature green stage of tomato was more preferable than those of fruits harvested at breaker stage. According to the results, mature green stage of Yezin-2 tomato variety is more suitable for long storage period.

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APPENDICES

Appendix 1. Monthly Record of Minimum and Maximum Temperature from November 2009 to April 2010

Month	Temperature (˚C)	
	Maximum	Minimum
November	34.06	18.91
December	30.86	16.54
Junary	31.40	15.73
Februry	34.64	15.57
March	36.06	20.14
April	36.75	23.56

Appendix 2. Monthly Record of Minimum and Maximum Temperature from December 2010 to May 2011

Month	Temperature (˚C)	
	Maximum	Minimum
December	32.47	15.53
Junary	33.85	16.54
Februry	36.23	17.00
March	38.23	21.82
April	41.91	24.82
May	38.69	26.38

Appendix 3. Daily Record of Minimum, Maximum Temperature and Relative Humidity at Ambient Condition for 2010 and 2011

Date	In 2010		Date	In 2011	
	Temperature (˚C)	Relative Humidity% (RH)		Temperature	Relative Humidity% (RH)
10.2.10	31	47	17.3.11	31	47
11.2.10	31	42	18.3.11	31	53
12.2.10	31	49	19.3.11	31	48
13.2.10	30.5	49	20.3.11	32	52
14.2.10	30	37	21.3.11	33	57
15.2.10	31	50	22.3.11	32	59
16.2.10	30	49	23.3.11	31	60
17.2.10	30	48	24.3.11	32	60
18.2.10	31	50	25.3.11	31	63
19.2.10	30.5	47	26.3.11	33	64
20.2.10	32	53	27.3.11	32	52
21.2.10	32	58	28.3.11	32	57
22.2.10	31	61	29.3.11	33	59
23.2.10	32	59	30.3.11	31	60
24.2.10	31	58	31.3.11	34	50
25.2.10	32	58	1.4.11	33	49
26.2.10	32	49	2.4.11	32	53
27.2.10	30	54	3.4.11	31	44
28.2.10	32	52	4.4.11	32	50
1.3.10	31	50	5.4.11	33	56
2.3.10	31	48	6.4.11	33	51
3.3.10	31	49	7.4.11	32	50
4.3.10	32	53	8.4.11	33	59
5.3.10	33	44	9.4.11	32	60
6.3.10	32	50	10.4.11	30	60
7.3.10	31	56	11.4.11	30	63
8.3.10	32	45	12.4.11	32	64
9.3.10	31	50	13.4.11	33	62

Appendix 4. Nutritional Value of Tomato

Nutritive value of 100 gm edible portion	
Water (%)	95
Energy (kcal)	18
Protein (g)	0.9
Fat (g)	0.2
Carbohydrate (g)	3.9
Fiber (gm)	1.2
Ca (mg)	10
P (mg)	24
Fe (mg)	0.3
Na (mg)	5.0
K (mg)	237
Vitamin A (IU)	833
Thiamine (mg)	0.04
Riboflavin (mg)	0.02
Niacin (mg)	0.6
Ascorbic acid (mg)	12.7

Appendix 5. Analytical Analysis of Chicken Manure and Chemical Fertilizers

Sr. No.	Description	N (%)	P_2O_5 (%)	K_2O(%)
1.	Urea	45.41		
2.	T-super		22.37	
3.	Potash			59.86
4.	Chicken manure	1.73	0.92	1.13

(A) Control

(B) Urea alone

(C) Chicken manure alone

(D) 25 N + CM

(E) 50 N + CM

(F) 75 N + CM

Plate 2. Experimental plots of tomato treated with urea fertilizer and chicken manure

Plate 3. Experimental tomato field



(A) Control (B) Urea alone (C) Chicken manure alone



(D) 25 N + CM (E) 50 N + CM (F) 75 N + CM

Plate 4. Tomato fruits harvested from the plant treated with the urea fertilizer and chicken manure (A) control, (B) Urea alone, (C) Chicken manure alone, (D) 25 N + CM, (E) 50 N + CM and (F) 75 N + CM

Plate 5. Postharvest storage of tomato fruits at ambient condition

(A)

(B)

Plate 6. Effects of urea fertilizer and chicken manure on postharvest quality of tomato at (A) 16 DAS and (B) 20 DAS