EFFECT OF DIFFERENT STAKING METHODS ON YIELD AND QUALITY OF INDETERMINATE TOMATO (*Lycopersicon esculentum* Mill) VARIETIES UNDER JIMMA CONDITION, ETHIOPIA

M.Sc. THESIS

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EFFECT OF DIFFERENT STAKING METHODS ON YIELD AND QUALITY OF INDETERMINATE TOMATO (*Lycopersicon* esculentum Mill*)* VARIETIES UNDER JIMMA CONDITION, ETHIOPIA

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BY

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APPROVAL SHEET

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As thesis research advisors, we hereby certify that we have read and evaluated this thesis prepared, under our guidance, by Amina J. Gojeh, entitled Effect of Different Staking Methods on Yield and Quality of Indeterminate Tomato (*Lycopersicon esculentum Mill*.) Varieties Under Jimma Condition, Ethiopia. We recommend that it be submitted as fulfilling thesis requirement.

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As members of the *Board of Examiners* of the *M.Sc. Thesis Open Defense Examination, w*e certify that we have read, evaluated the thesis prepared by Amina Jatau Gojeh and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Horticulture (Vegetable Science).

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Internal Examiner Signature Date

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External Examiner Signature Date

DEDICATION

My research work is dedicated to my children (Lucy, Albert, Mary, Barnabas and Cleopas A. Gojeh) for their support and encouragement. To my father (Late Dangiwa Yari), who passed away shortly after my first year of registration and lastly to my beloved Husband who stood by me during the death of my father and the encouragement he gave me during the study.

STATEMENT OF THE AUTHOR

I declare that this thesis is my work and all sources of materials used for this thesis have been acknowledged. The thesis is submitted in partial fulfillment of the requirements for M. Sc. Degree at the College of Agriculture and Veterinary Medicine and is deposited at the University Library. I solemnly declare that, this thesis is not submitted to any institutions elsewhere for award of any degree, diploma, or certificate.

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Name: Amina J. Gojeh   Signature _______________

Place: Jimma University, Jimma.

Date of submission: ______________________

LIST OF ABBREVIATIONS

BPEDORS	Bureau of Planning and Economic Development of Oromia Regional State
MARC	Melkassa Agricultural Research Center
NGA	National Gardening Association
NPB	Number of primary branches
OECD	Organization for Economic Co-operation and Development

BIOGRAPHICAL SKETCH

The author was born on 12th December, 1958 in Kushe, Kagarko Local Government Area of Kaduna State, Nigeria. Started her primary education from St. Patrick primary school, Ungwar Jakada from 1969-75. Then she proceeded to then Women Teacher's College Kaduna from 1979-83 where she obtained Grade Two Certificate. In 1989-1991, she attended the then Advanced Teacher's College Zaria where she studied Biology/Chemistry and obtained Nigeria Certificate in Education. The author went to Ahmadu Bello University Zaria where she obtained her B.Sc degree in Biology from 1994-99.

Her working experiences started as a classroom teacher in Premier Nursery School Kaduna, from 1984-86 and later joined Kachia Local Government in 1987-1991where she was posted to LEA primary School, Dogon Kurmi as a classroom teacher. In 1991 she was transferred to Kaduna North Local Government, there she was posted to LGEA primary school Ungwar Dosa from 1991-92. Thereafter, posted to LGEA primary school Ungwar Shanu where she taught from1992-98. In 1998-2002, she was selected among others to Science Primary School Kawo, Kaduna to teach science. In 2002-2005, an inter-state transfer to federal capital territory (FCT Universal Basic Education Board) was made to Abuja; where she was posted to LEA Karmo Tsoho, Abuja. She was again in 2005, posted to Junior Secondary School Gwagwa, Abuja where she taught for one year and then voluntarily retired in November 2006 from service to join her husband in Ethiopia.

While in 2005 was awarded Teachers' Certificate Registration by the Teachers' Registration Council of Nigeria.

From 2007 to date, a student in Horticulture Department, College of Agriculture and Veterinary Medicine, Jimma, Ethiopia. The author is married and blessed with five children.

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ABSTRACT

Tomato (Lycopersicon esculentum Mill) is amongst the most important fresh vegetables used world wide including Ethiopia. Ethiopia is characterized by warm, dry day and cooler night which are favorable for optimum growth and development of tomatoes. Recognizing the importance of staking to reduce the effect of high moisture stress and disease incidence on yield and quality of tomatoes, a field study was conducted on the effect of different staking methods on yield and quality of indeterminate tomato varieties under Jimma Condition, at the experimental field of Jimma University, College of Agriculture and Veterinary Medicine, Jimma. Miya, Marglobe and Metadel varieties were used, while the staking methods were single post staking (T_1), single string staking (T_2), French type staking (T_3) and the non- staking (T_0). A Randomized Complete Block Design with three replications was used. The result obtained showed highly significant ($P<0.001$)interaction effect between the staking methods and varieties per plant on plant height, number of marketable and unmarketable fruits, marketable and unmarketable fruit yield, fruit shape index, titratable acid (TA), Total Soluble Solids (TSS), and sugar-acid ration, root, stem and fruit dry matters. Number of flowers and fruits set per cluster were also highly significant amongst the varieties and the staking methods. The main effect revealed that amongst the staking methods, French type staking gave the highest number of flowers (73.6); whereas, amongst the varieties, Miya had the highest number of flowers per plant (75.26). Similarly, the highest number of fruits set was recorded from the same variety, while the three staking methods did not differ from each other but only differ from the non- staked control. The highest number of marketable fruit was found from Miya variety with French type staking (27.53), while the lowest number was observed from the non-staked control. The correlation coefficient strongly supported the result as significantly positive relationship between the number of flower with fruit set ($r = 0.95$), and number of marketable fruit ($r=0.71$). The highest numbers of unmarketable fruits per plant were recorded from Metadel with non-staking (20.86) and the lowest number was from French staked Miya, which did not significantly differ from single string and single post staked maglobe. The highest marketable fruit yield per plant was observed from Metadel with French type staking (1.75kg) per plant but the least was obtained from Miya with non-staking (0.64kg. In terms of the Total sugar, Miya was found to contain more sugar 4.64%. High percentage of late blight and fruit rot were mainly recorded from control plots. Blossom end rot was high where Miya and metadel were not staked. The profits recorded were high from French type staking of Metadel though not significantly different from single post and French type staked Miya. Least profit was obtained from non- and single post staking of Metadel and are thus recommended for better yield and quality. While staking methods need to be studied along with pruning and types of animals and birds that are pest to tomato fruits under Jimma condition in Ethiopia.

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is a vegetable widely grown in the world. It belongs to the family Solanaceous, genus *Lycopersicon,* subfamily Solanoideae and tribe Solaneae believed to originate from Andean region of South America. The family also contains bell peppers, hot peppers, eggplants, and Irish potatoes (Konsler and Gardner, 1990). The plant is an annual or short-lived perennial and grows as a series of branching stems, with a terminal bud at the tip that does the actual growing. When the tip eventually stops growing, whether because of pruning or flowering, lateral buds take over and grow into other fully functional vines. The vines are covered with fine and short hairs, which facilitates the veining (running) these vines can turn into roots wherever the plant is in contact with the ground and moisture and where staking is not provided. Most tomato plants have compound leaves called regular leaf (RL) plants and some cultivars have simple leaves known as potato leaf (PL) style because of their resemblance (Onwueme, 1979).

Tomato is a warm season vegetable, which can be grown under a wide range climate and soil conditions. It can be successfully grown on most soils, but preferably a well-drained, sandy loam, loam, or clay loam soils with a pH of 6.0 to 7.0 that may likely reduce blossom end rot symptoms on fruit (Kemble *et al.*, 2000). An experiment showed that, nitrogen, phosphorus, potassium, sulfur, calcium and iron all increased in the plant foliage with oxygen enrichment in the root zone as compared to the control plants. Tomatoes grown on soils with a pH of 6.0 to 7.0 are less likely to show blossom-end-rot symptoms on the fruit (Morgan, 2004)

In general, the optimum temperature required for tomato cultivation is 15^0C- 27^0C (Chadha, 2006). The temperature for most varieties lies between 21 and 24^0C; however, the plant tissues are damaged below 10^0C and above 38^0C, below 21^0C can cause fruit abortion in tropical lowland. Light intensity affects the color of the leaves, fruit set and fruit color (Kemble *et al*., 2000). In Ethiopia, the optimal day temperature for growth and quality fruits is between 24 and 28^0C and the night temperature ranges between 14 and 17^0C (Lemma, 1998). Also the altitude is between 700-2000 mm which is characterized as warm and dry day and cooler night and is favorable for growing tomato. A temperature range between 21-27^0C day and 10-20^0C night is suitable for plant development and fruit set and fruit setting is poor with either high or low temperature. When the temperature is extremely high, it causes flower drops and poor fruit set. Lemma, added that tomato is grown in a well-drained friable sandy loam soil with pH of 6.7 for early and high fruit yield.

The tomato plant is about 1-4 m in height and has a weak, woody hairy and glandular stem that often vines over other support materials. The leaves are spirally arranged with about 15-50 cm long and 10-30 cm wide. Leaflets are ovate to oblong, covered with glandular hairs. Inflorescence is clustered and produces 6-12 flowers. Petiole is 3-6 cm. The flowers are 1–2 cm, grown opposite or between leaves, mostly yellow, short calyx tube and hairy. It has usually 6 petals of up to 1 cm in length, surrounding the style with an elongated sterile tip. Ovary is superior and with 2-9 compartments; mostly self and partly cross-pollinated. Bees and bumblebees are the most important pollinators. The fruit is freshly berry with varied shape such as globular, round, pear and oblate, 2-15 cm in diameter. The immature fruit is green and hairy. Ripe fruits range from yellow, orange and red. Fruit has numerous seeds, kidney or pear shaped. They are hairy, light brown, 3-5 mm long and 2-4 mm wide. The embryo is coiled up in the endosperm. The weight of 1000 seeds is approximately 2.5-3.5 g (Shankara *et al.,* 2005).

There are many tomato varieties grown for various purposes such as Heirloom tomato (it is a wild variety, which is popular among home gardeners and organic producers because it produces more interesting and flavorful crops at the cost of disease resistance and productivity) and Hybrid tomato which is more common and tends to be produced heavily (Reiners, 2004). Furthermore, tomato is classified as determinate, indeterminate and semi-determinate. Determinates or bush type of tomatoes grow and bear fruits at once and top off at a specific height. They stop growing because the main stem forms a flower bud at the top that produces fruit.

Indeterminate varieties develop into vines that never stop growing and continue producing until killed by frost. Tall varieties are the best choice for long harvest period because they keep growing after flowering, however, under tropical conditions, diseases and insect attacks may stop the growth. Home growers and local-market farmers who want ripe fruit throughout the season usually grow them (Welsford, 2008). Tall tomato plants generally have more foliage that can keep the temperature lower within the crop and the fruits grow in the shade of leaves, sun does not damage the fruits and they ripen more slowly. Among the researchers (Nzanza, 2006) indicated that, slower ripening and high leaves ratio improve the taste of tomato fruits, particularly the sweetness. Semi-determinate types lay between determinate and indeterminate types; they produce suckers like indeterminate type, the height of the plant is 0.91-1.52 m (Reiners, 2004).

Tomato varieties are also divided into several categories, based mostly on shape and sizes. Such varieties are globe tomatoes, which are produced for processing and fresh eating. There is the Beefsteaks tomato, which is large tomatoes with kidney-bean shape and thinner skin; often used for sandwiches. There are Plum tomato or paste tomatoes (including pear tomatoes) with high solid content; this is used in tomato sauce and paste and lastly, Cherry tomato which are small and round, often sweet, generally eaten whole in salads (Adeboye *et al.*, 2006).

A number of tomato varieties have been recommended and released for production in Ethiopia. These include Marglobe, Melka Shola, Melka Salsa, Roma VF, Napoli VF, Money Maker, Heinz-1350, Eshet, Person A-1 Metadel and Miya. Tomato is the most important and widely grown vegetable in Ethiopia. Small-scale farmers grow tomato for the local and regional markets, while large-scale farmers supply such to local markets and exports. The total area under tomato cultivation as reported by Ethiopian Investment Agency (2008) in 2007/2008 seasons was 36,382 hectares, and the total production was 7,729,141 tons. Small-scale farmers produce the bulk of fresh market tomatoes and processing types are mainly produced in large-scale farms (EARO, 2004).

Tomato has been widely accepted and commonly used in varieties of dishes as vegetable, used raw as salad, cooked or processed products. Tomato is recognized as the source of vitamins and minerals. It can be processed and canned easily as tomato paste, tomato ketch up, whole peel-tomato, juice, sauce and tomato powdered that produced for local market and export. In addition, tomato farming is a good income-generating enterprise to many farmers and provides employment in the production and processing industries. Health wise, the pigment that gives the red color in tomato fruits known as lycopene, the pigment reduces prostate and lung cancer, lowers cholesterol in blood impact natural pigment to food, cosmetic and pharmaceucal industries (Ship, 2000).

The constraint of tomato production in Ethiopia is the incident of diseases caused by bacteria and fungi, which affect yield and quality (EARO, 2004). Early blight (*Alternaria solani*) and Late blight (*Phytophthora infestans)* are known to be the most devastating diseases of tomato in Ethiopia which are caused by fungi, these diseases occur at any time during the growing season. The fungi becomes inactive during dry periods and found to survive in the soil and crop debris where they infect the tomato fruits and leaves when the soil is moist by rain or irrigation. This problem can be overcome by staking EARO (2004). Lack of appropriate cultural practices during wet and dry seasons could be one of the crucial barriers to a successful tropical tomato production and suggested that, the risk of growing tomato in the tropics could be reduced by staking; using the improved cultural practices of fence and wire method. Although, fence and wire method of staking may not be an economical venture, in Ethiopia, especially to the small-scale farmers. Therefore, the present study intended to assess the different staking methods that use only the available local materials and afforded to the majority of farmers in Ethiopia. This may help to identify the cheapest method (s) that can fetch good quality and high tomato yield and also prevent the leaves and the fruits from bacteria and fungal diseases (Ariyarathne, 1989).

Diver *et al*. (1999) defined staking as a training system used in tomato culture; the training is in from wire cage, trellis or wood staking. The authors reported a result of study that ranked some qualities of tomato obtained from staking method, like early fruiting, fruit size, marketable yield, fruit cracking, fruit rotting, fruit quality, fruit sunburn and cost/acer compared to wire cage and trellis methods that were ranked third and forth. Though the name of the staking method used was not mentioned.

EARO (2004) stated the different methods of staking with bamboo materials and wire fence practiced in the rain seasons included; triangle with horizontal bamboos, single stake with horizontal bamboos on each side, single stake and bench stake. The result showed that, there were highly significant yield differences among the treatments. The non-staking treatment gave the lowest yield of 22.6 tons/ha, single and the other staking methods gave significantly higher marketable yield than the non- staking. Among the six staking treatments, the bench methods gave the highest yield of 41.89 tons/ha followed by the triangular method of 37.88 tons/ha, while the fence and wire method resulted to high economic loss because of the labor and material costs.

Previous works on staking methods in Ethiopia and elsewhere seem to have been on the comparison of staking and pruning in the rainy season to examine fruit quality, for increasing yield and continuous income to the producers. However, the studies were yet to be performed on the effects of the different staking methods on tomato varieties under irrigated conditions and under Jimma condition. This study therefore is on the “Effect of Different Staking Methods on Yield and Quality of Indeterminate Tomato (*Lycopersicum ensculentum* Mill) Varieties under Jimma Condition’’. It has the following specific objectives:

1. To assess the effect of different staking methods on yield and quality of indeterminate tomato (*Lycopersicon esculentum* Mill) varieties under Jimma condition
2. To determine the interaction effect of different staking methods and varieties on yield and quality
3. To estimate the economic efficiency (feasibility) of staking using the varieties

2. LITERATURE REVIEW

2.1. Tomato cultivation

Tomato is the most widely grown vegetable in the world (Ariyarathne, 1989). Tomato varieties are available from seed companies, however, adapted only to specific areas (Gaus *et al.,* 2004). According to Abdullahi *et al. (*2009), *Lycopersicum esculentum* Mill is thought to be a direct ancestor of cultivated tomato based on its wide presence in Central America and shortened style length in the flower. The author reported that, *L. esculentum* has been classified into five botanical varieties as shown in Table 1 below.

Table1. Botanical varieties of cultivated tomato (*Lycopersicum esculentum* Mill)

Botanical Variety	Common Name
Commune	Common tomato
Cerasiforme	Cherry tomato
Pyriforme	Pear tomato
Grandiforme	Potato leaved tomato
Validium	Upright tomato

Source: Abdullahi *et al.* (2009)

In Ethiopia, Marglobe was one of the varieties released to farmers by Melkassa Agricultural Research Center. It was described as a variety that gave high yields ranging from 650-830 kg/ha and was recommended for Debre Zeit region. However, other varieties like Serio, Red Pear, Royal ball and Nova 70 were found to be superior in marketable and total yield across locations (Lemma, 2002). A field experiment was conducted on Vertisols at Ambo College, Ethiopia, during 2003/2004 and 2004/2005 cropping seasons; to investigate the response of tomato cultivars varying in growth habit to rates of Nitrogen (N) and Phosphorus (P) fertilizers and plant spacing.

The result showed that cultivar Marglobe had significantly higher mean plant height (72.8 cm) than a determinate cultivar Melka Shola (64.9 cm) (Balemi, 2007). However, other varieties like

Miya (*Floralou*) and Metadel (*Caraibo*) were released for production in 2007 and 2005 as new varieties, respectively (MoARD, 2005; MoARD, 2007).

2.2. Factors Affecting Tomato Fruit Quality

Growing tomato is not an easy task since the plant is exposed to many conditions such as diseases, climate, nutrition as well as genetic factor. The fruit itself has to meet certain market requirement that attract consumer`s preference, such as the physical appearance of the fruit that include color, shape, firmness, and freedom from defects and decay (Nzanza, 2006). High yields combined with high quality are common requirement of tomato grower. These could be achieved if the above mentioned conditions are maintained (Dorais *et al*., 2004)

2.2.1. Climatic condition and cultural practices

Tomato is a warm-season vegetable and grown extensively in cool seasons. At high and low temperatures, there is low germination of seeds, poor plant growth, flower drop, poor seed set and ripening. At high temperature, quality of tomato fruits is poor and there is high incidence of sun-scald. Under extreme high and low temperature conditions, the yield and quality of fruits is reduced. Mild winter condition is ideal for seed germination, plant growth, fruit set, fruit development and ripening. An excessive rain adversely affects fruit setting, flower drop, and fruit rotting (Chadha, 2006).

Rain is another serious factor that affects tomato growth, yield and quality (Weerakkody *et al*., 1996). In their study on yield and quality of tomato as affected by rainfall during different growth stages. They reported that, late flowering and fruit ripening could be identified as critical growth stages in terms of rain damage that may affect the yield and yield components.
At fruit growth stages, rain increased fruit cracking and fruit juice pH, but at ripening stage, reduced fruit cracking and juice pH but increased fruit defects. Humidity played a great role in tomato production. It tends to temper with the effect of temperature. High humidity is more conducive to heavy dew at night, which reduces moisture stress. However, favors the development of diseases (Welsford, 2008).

2.2.2. Pre-harvest and postharvest factors affecting quality

Pre-harvest factors mean the factors that affect the produce when still attached to the mother plant, while the harvest and postharvest factors are the factors that affect the produce during and after harvest.

Harvesting tomato fruits when they are unripe and not yet developed full flavor, affects the quality of the cultivar at physiological maturity of the fruit at harvest, post harvest handling requirements and conditions (Kader, 1983). Post harvest qualities of tomatoes partly depend upon pre-harvest factors such as cultural practices (such as nutrition, water supply and harvesting methods), genetic and environmental conditions. Similarly, quality management starts in the field and continues until the produce reaches the end users (Meaza *et al.,* 2007).

2.3. Post-harvest Quality Changes during Ripening in Tomato

2.3.1. Postharvest chemical changes

During ripening of tomato fruits, the starch degradation takes place resulting to glucose or fructose formation, the fruit becomes soft due to increase in polygalacturonase and soluble pectins production, which genes raise to flavour and aromatic compounds (Paran *et al.,* 2007).

2.3.2. Total soluble solids

Tomato fruit contains solids (°Brix) with about 95% water and 4-5% organic compounds called solids. The solids portion consists of about 50% sugar (glucose and fructose) found mostly in the fruit wall; 25% is alcohol insoluble solids, which includes pectins, cellulose, proteins, polysaccharides; and organic acids, mostly citrate and malate. The remainder of the solids consists of carotenoids, volatile compounds, amino acids, and inorganic compounds. High solids content is important for processed tomato, especially paste. However, yield and solids content are negatively correlated (the higher the yield the lower the solids (Grierson and Kader, 1986). Water deficit was found to increase fruit soluble solids level (Mitchell and Shennan, 1991).

2.3.3. pH and titrable acidity

Sugar acid ratio is responsible for the characteristic flavor of many fruits. At the beginning of the ripening process, the sugar/acid ratio is low, because of low sugar content and high fruit acid content, this makes the fruit taste sour. It has been reported that, the acidity pH of tomato fruit ranges from 4-5, and pH less than 4.5 is required for processed tomato, because microbial growth is inhibited. Although, pH above 4.5 are unacceptable for processing purposes, but that sour taste is said to be desirable in some countries (Davies and Winsor, 1969). In addition, during ripening process, the fruit acids degraded and the sugar content increases, hence the sugar acid ratio achieves a higher value. Over ripe fruits have very low levels of fruit acid that makes it to loss its characteristic flavour. Marked differences in tomato fruit acidity were consistently observed between varieties and varietal differences in sugar content were generally similar. Higher acid concentrations resulted from water deficit irrigation and from irrigation with saline water. However, fruit acid concentration in control plots declined during the period of fruit development (Mitchell and Shennan, 1991).

2.3.4. Dry matter content

Globally, there is an increase in competitive fresh produce market; more attention is given to fruit quality traits and consumer satisfaction. Recent surveys indicated that sweeter fruit with better flavour are generally preferred. Carbon accumulation strongly influences the development of fruit taste and starch is the major component of dry matter content. Surveys indicated that, there is strong correlation between at-harvest dry matter and starch content, and soluble solid concentration and flavour when fruit are eaten ripe. Genotypes are different in sink strength, which is the effect of sink size, and sink activity. However, fruit of different genotypes differed in dry matter content mainly because of differences in starch concentrations and dry weight accumulation rates, irrespective of fruit size (Heuvelink, 2010).

Sandril *et al*., (2003) showed that, the dry matter content of control (un-shaded) and shaded plants differed significantly as 974.9 gm^{-2} and 762.5 gm^{-2} for total dry mass , 550.1 gm^{-2} and 419.74 gm^{-2} for fruits , and 424.75 gm^{-2} and 342.74 gm^{-2} for vegetative organs. Similarly, another study indicated that no significant influence on distance (transport resistance) between source and sink on dry matter partitioning hence 58–60% of dry matter was found in fruits for control plants, whereas for both double-shoot treatments was 43% (Heuvelink, 2010). Cock-shull and Ho (1995) reported that fruit are the strongest sinks for assimilates in tomato; other organs are weaker sinks for assimilation. The competition for assimilate is related to the rate of truss initiation, the number of fruit set on each truss and duration of fruit development. The proportion of available assimilate partition to fruit can account for about 65% and 69% of the dry weight of the above ground part.

2.4. Disease incidence

Disease is one of the major constraints affecting tomato plants at different growth stages and at post-harvest, which can reduce the quality and yield of tomato. It can cause complete loss of crops in the field when there are suitable temperature and moisture, high relative humidity and less sunlight. High night temperatures increase the disease incidence.

The most common diseases in tomato production in the field are septoria leaf spot (*Septoria lycopersici),* late blight (*Pytophthora infestans),* early blight (*Altenaria solani*), powdery mildew *(Leveillula taorica*) and viruses as well as root-knot nematodes. According to Fry (1998), Late blight (*Pytophthora infestans*) is a disease of potato and tomato that is encouraged by rain or humid weather, damaging the leaves, branches and causes brown, dark spots on the fruits whereas early blight (*Altenaria solani*) disease; defoliates the leaves and exposes the fruits to sunburn which affects the marketable yield and quality of fruits (Lemma, 2002).

Disease and physiological disorder are attributes that affects tomato fruit at pre-harvest stage (Gleason *et al*., 2006). Most physiological disorders affect the skin of tomato leaving the underlying flesh intact while others affect only the flesh such as blossom end rot, cracking, cat facing, puffing or misshapen (Peet, 1992). Blossom end rot had been associated to calcium deficiency in the soil (Wills *et al.,* 1998).) They also found that, reducing the number of fruits, increases fruit size which is caused by flow of water and nutrient into the fruits and when the fruit become saturated, it leads to fruit cracking and eventually favours the incidence of disease (Peet and Willits, 1995). According to Cheryld *et al*. (1997) and Considine *et al*., (1981), tomato grown without staking are more prone to fruit cracking due to exposure of fruits to direct sunlight and high fruit temperature and distribution of source growth. Severe leaf spot disease caused significant reduction in fresh pod length, dry pod yield and grain yield, but did not affect the number of pods produced per plant. Brihanu and Tilahun (2010) reported that, small animals and birds fed more on Marglobe than Melka shola cultivar in Ethiopia.

2.5. Staking of Tomato

Staking or trellising is the use of bamboo, wood, metal poles, or other materials to support the plant and keep the fruit and foliage off the ground. Staking increases fruit yield and size, reduces the proportion of unmarketable fruit, and facilitates chemical spraying and harvesting (Kader and Morris, 1976). In addition, many tomato varieties need staking to produce high quality fruits and to avoid rotting of fruits when they are in contact with the soil.

Staking allows better aeration, reduces attacks of fungus diseases and ensures better exposure of the foliage to light for better photosynthesis (FAO, 1988). Plastic tunnele are used for protection of off season vegetables due to low temperature and chances of frost in an open field (Farooq *et al*. 2006).

Tomato plants are supported by 1.2 m high stakes to prevent the tomato fruits from being damaged by insects. At harvest, fruits damaged by insects are counted, the marketable fruits are size-graded (1-10 levels of sizes) and the number and weight of fruits in each grade are taken.

According to Ariyarathne (1989), countries like Phillippines, Taiwan and Mexico, usually grow tomato with supports to obtain earlier, clean and larger fruits. Spraying and harvesting are made easier when tomatoes are supported. The author listed some methods of staking tomato plants in the above countries that include single staking method, triangle staking method, bench staking method, single and horizontal method, and fence and wire staking method. The author added that, the cost of staking varies in different geographic localities; 13%, 30%, 25%, and 12% in Columbia, Phillippines, Taiwan and Mexico respectively. The methods of staking tomato also vary according to the plant type, the availability of staking materials and the individual requirement. He compared the yield and quality of tomato obtained from mulching and staking methods which was used with wood and fence wire. The result showed that, the bench and triangle methods gave significantly higher yields and higher returns, while the fence and wire method resulted to big economic loss because of its labor and material costs.

Oyenuga (1968) recommended staking as the leaves of Telfaria species are palatable and nutritious and are very much cherished by goats. Therefore, staking can be used to protect vegetables from animals, diseases and also provides good quality vegetables. Akoroda *et al.* (1990) and Trenbath (1976) supported the idea of staking because it facilitates harvesting of the leaves and pods and exposes the leaves for effective light reception; as light is one of the factors needed by leafy vegetables. Staking also reduced the incidence of blossom end rot and fruit crack in tomato. In contrast, Welsford (2008) stated that, staked tomatoes are more susceptible to cracking, blossom end rot and sunscald problems and the total yield of staked plants is often lower than similar plants that are not staked.

An experiment was conducted to examine the relative marketable leaf yield of fluted pumpkin (*Talfaria occidentalis*) on staked and un-staked bases using 4 x 4 randomized complete block design for three planting seasons 2003 to 2005. The result revealed no significant difference in marketable leaf yield between the staked (500.0 to 500.5 g) and un-staked (498.3 – 499.5 g) plants. The researcher concluded that, elimination of cost of stakes and staking operation would be of better economic return on revenue to farmers (Egun, 2007).

Lemma (2002) described staking as an important production practices used by tomato growers mainly in the raining season. Staking experiment was done at Melkasa Research Centre on Money Maker and Heinz-1350 varieties and the result produced a yield of 6 and 6.5 tons/ha, respectively over un-staked plants. Staked tomato plants gave high yield of 58.3 tons/ha and 57.3 tons/ha compared to the low response of 39.9 tons/ha and 33.4 tons/ha for un-staked plants of Marglobe and Money Maker in 1993. Lemma further confirmed that, staking of tomatoes plants for fresh fruit market increased yield and quality of fruits.

According to Reiners (2004) upright plant dries off more quickly following rain or morning dew. It lessens disease problems since wet foliage is a breeding ground for all kinds of fruit and leaf diseases. Growing plants upright will eliminate disease such as anthracnose and buckeye rot these rots as well as lessen problems with slugs, mice and other pests, both large and small. Fruits can be seen and pick without breaking branches off the plant as you search.

Hanson *et al*., (2001) stated that, indeterminate varieties should be staked to facilitate pruning, pinching, harvesting, and other cultural practices. Staking provides better growth of tomato plant and branches, increased fruit bearing, and improved quality of fruits. It aids cultural operations like fruit picking, spraying, weeding, fertilizers application and ear thing up. They added that, staking can be done by two methods. First method is that the sticks of 1.5-2.0 meter length and 2.5 cm thickness are staked by the tomato plant as it grows. In the second method, a network of wire and bamboo is formed with the help of Sutali (small rope) branches. Staking and pruning can improve yield and fruit size, reduced fruit rot incidence and more convenient for crop care and makes harvest easier for the workers, commented in their guide on green beans ecology (FAO, 2007).

2.6. Yield of Staked Tomato

Yield is an important parameter in fruit production. Researchers reported that, frequency of water supply could lead to low yield and the fruit quality (Maboko, 2006). In addition, increase in the rate of irrigation can lead to low soluble sugars and the dry matter of tomato fruits with high or poor crop yield. The work of Ariyarathne (1989) showed that, there were highly significant yield differences among the staking methods. The non-staking treatment gave the lowest yield of 22.66 tons/ha, the triangle method was 37.88 ton/ha, the bench method recorded the highest yield of 41.89 tons/ha and the single staking gave significantly higher marketable yield than that of non-staking. The outcome of the experiment also revealed that the number of marketable fruits per bench method gave the highest number of marketable fruits, while the non-staking method gave the lowest number. Chadha (2006) reported that, training of tomato is required to produce better quality fruits.

Adeniyan *et al.* (2007) revealed that, staking is important in African yam bean grown as a sole crop when grown intercropped with other crops. The result of their research showed the highest average plant height of maize and kenaf were recorded from intercropping of maize, kenaf and African yam beans as 2.60 cm and 2.86 cm compared with the lowest plant height recorded as 2.09 cm and 2.15 cm from sole maize and kenaf. Similarly, the highest yield of African yam bean seed was obtained from intercropped maize, kenaf and African yam bean 0.86 ton/ha, kenaf and African yam bean 0.88ton/ha and the low yield was from sole African yam bean as 0.49 tons/ha.

The researcher attributes the increase in plant height and yield in intercropped system to component crops competition for light, which favors the component crops with leaf area that are higher in the canopy and the ability of African yam bean to get life stakes for efficient growth.

Anuebunwa (1994) stated that, the use of live guinea corn for staking 200 g yam sett size with a cost outlay advantage of 25.03% gave the highest profit and stimulated yam production. This result was recorded from two year farm level trial on live guinean corn (*Sorghum bicolour* L. CV KSV8) and maize (*Zea mays* L. CV TZSRW) as alternative yam staking materials were compared. Saunyama and Knapp (2003) revealed that, the effect of pruning and trellis on red spider mite incidence and control, the unpruned and untrellised plots had 37.7 and 30.2 mites per leaf while the pruned and trellised plots had 4.6 and 17.3 mites per leaf and chemical control was more effective on the pruned and trellised plots which resulted in yield increased of 60%. Therefore, they recommended pruning and trellis as the best cultural practices to manage disease incidence, fruit rots, reduce mites and damage in fruits.

3. MATERIALS AND METHODS

3.1. Description of the Experimental Site

The experiment was conducted in the experimental field of Jimma University College of Agriculture and Veterinary Medicine, in Jimma, Ethiopia on 29th October 2009 to April, 2010. There was fluctuating weather; with unstable rainfall and dry weather. The site used for the experiment is located in Oromia Region/State in the South-western part of Ethiopia, 343 km away from Addis Ababa, with altitude of 1710 meters above the sea level (m.a.s.l.), with latitude $7^0$42'' N and longitude 36^0 50"E. The minimum and maximum temperatures were about 11.4^{O}C and 26.8^{O}C, respectively.

3.2. Experimental Materials

In the experiment, three tomato (*Lycopersicom esculentum* Mill) varieties were used (namely: Marglobe, Metadel and Miya) from Melkassa Agricultural Research Centre (MARC) for the study (Table 2).

Table 2. Tomato varieties and their characteristics used in the experiment

Variety	Year of release	Area of Adaptation		Maturity days	Yield (tons/ha)	Temper a ture (^{0}C)	Growth habit	TSS	pH
		Altitude (m)	Rainfall (mm)						
Marglobe	1976	700-1800	Irrigated	62-89	18-20	21-32	Indeter minate	4.0	4.6
Metadel	2005	700- 1800	Irrigated	75-85	34.5	21-32	" "	4.4	4.7
Miya	2007	500- 2000	Irrigated	82-89	47.1	21-27	" "	4.0	4.5

Source: MoARD (2005, 2007 and 2008)

Four staking methods (single post staking, French type staking, single string staking and control /without staking) were also used as reflected in Table 3.

Table 3. Treatment Combinations for Tomato Varieties with Staking Methods

Varieties	Staking methods

V_1	Marglobe	S_0 (Control/ Without staking)
		S_1 (Single post staking)
		S_2 (Single string staking)
		S_3 (French type staking)
V_2	Metadel	S_0 (Control/ Without staking)
		S_1 (Single post staking)
		S_2 (Single string staking)
		S_3 (French type staking)
V_3	Miya	S_0 (Control/ Without staking)
		S_1 (Single post staking)
		S_2 (Single string staking)
		S_3 (French type staking)

3.3. Experimental Design and Layout

Two factors (3 Varieties and 4 staking methods) were arranged in a Randomized Complete Block Design (RCBD), with three replications. The size of the experimental area was 6.72 m^2, the size of each plot was (2.4 m x 2.8 m) with spacing of 0.5 m between plots and 1.5m between block. The spacing between plants and rows were 30 m and 70 m, respectively. A plot had four rows that contained eight plants with the total of 32 plants per plot. The treatment combination is showed in Table 3 above.

3.4. Experimental Management

Ahead of the field plantation, the seedlings were raised on well prepared beds in the month of October. All agronomic practices were employed according to recommendation given by Ethiopian Agricultural Research Organization (2004) and Regina et al., (1998). Transplanting commenced when the seedlings were about 35 days old after hardening off was practiced. Fertilizer was applied at the rate of 200 kg DAP/ha DAP and 150 kg Urea/ha Urea. All DAP and 50% of urea was applied at time of transplanting and the other 50% urea was applied at a half month of transplanting. Proper irrigation water was applied as per the recommended frequency and time.

3.5. Staking of Tomato

Staking of tomato plants were done by using woods (*Eucalyptus camaldulensis*) and string (locally made). Four methods were used, these included single post staking, single string staking and French type staking and non-staking method as control for comparison. Woods of 3 cm thick and 175 cm heigh were used for all the staking methods. Stakes were driven into the soil up to 25 cm and the strings were tied at 25 cm above the ground when the plants were about 40 cm tall (FAO, 1988; NGA, 2009). The descriptions of the staking methods are as follows.

3.5.1. Single post staking

This is a method by which a pole is fixed in the soil – 25 cm depth and 5 cm away from each plant. Each plot consists of 32 poles of 175 cm height. A string of 187 cm was tied under a node loosely to avoid bruises to the stem and the string was wrapped around the pole, as the plant increased in height, the vines were trained by wrapping them on the string as reflected in "Plate 1" of Appendix B. When the plants started to develop primary branches and production of fruits, additional strings were used to support the plants.

3.5.2. Single string staking

In this type of staking, two poles of 175 cm were fixed in the soil, one at the extreme end of the opposite side of each row, a pole of 204 cm was placed across the two poles, at the meeting points between the two poles a tie was made together with a string to hold them tight. This is to prevent any disturbance by wind or the workers around the plots. A string of 215 cm was used to tie under a leaf node loosely and supported to the crossbar by wrapping the string two times and finally made a knot as reflected in "Plate 2 of Appendix B". However, as the plant increased in height and developed more branches with fruits, there was an increase in weight where additional strings were needed for more support.

3.5.3. French type staking

The staking was done using a pole of 175 cm, 25 cm of it was deeply fixed into the soil between two plants in each row, as the plant grew to the height of 6 cm height, a string of 620 cm was used to support the plants from running on the ground. The string was wrapped on the first pole at the extreme end of each row, two twists were made and the strings were separated into two; one to the left hand side of the plant while the second string goes to the right to support the plants side by side. This process continued to the last pole at the other end of the row as reflected in "Plate 3" of Appendix B. The process was repeated four times in each row at (6 cm interval) as the plant continued to grow.

3.5.4. Non-staking (control plots)

The non staking plots were left free to grow without staking as reflected in "Plate 4" of Appendix B.

3.6. Data Collected: The data on growth yield and quality response variables were collected from two middle rows of each plot. Eight plants were randomly selected from the two middle rows. Data recorded on growth response variables were as follows:

Average plant height (cm): The average height of the eight randomly selected sample plants from each plot were measured using a meter tape from the ground level to the terminal end after the sixth harvest.

Number of primary branches: Branches developed from the main stem were counted from the eight sample plants and the averages were taken as number of primary branches.

Days of flowering: The number days at which 50% of plants flowered was recorded from the eight sample plants of each variety from transplanting day (4^{th} December 2009).

Number of flowers per cluster: The number of flowers per cluster of the sample plants were counted and recorded. The sample plants 1-8 were tagged with coloured polythene bags to differentiate them as: Blue=1, White=2, Pink=3, Light blue=4 Ash=5, Black=6, Yellow=7 and Green=8. Then, the clusters on each of the plants were again represented with coloured polythene bags by separating them into lower, middle and upper level clusters. The lower level was regarded as the first clusters produced by the plants within two weeks, followed by another two weeks as middle level and then the last level after weeks was upper level. In each level, clusters were tagged with different colours of polyethene bags to differentiate the number of clusters of the sample in each plot as: Orange=A, Black=B, Pink=C, Blue=D, White=E, Yellow=F, White rope=G, Ash=H and Light yellow=I. The flowers were counted from each cluster of every level according to how they were tagged and recorded.

Number of fruits set per cluster: The number of fruits set per cluster were counted and recorded, following the same procedure above at immature green stage.

Fruits set percentage: The fruit set percentage was calculated as the ratio of the total number of fruits set and divided by the total number of flowers and times hundred.

Average number of fruits per plant (no.): From the six harvests made, at the end of each harvest, the total number of fruits was counted and recorded. The total numbers of fruits were divided by the number of sample plants to get the average number of fruits per plant and the result was used to multiply by the number of plants per plot to get the total number of fruits per plot.

Average fruit weight (g): The fruits harvested from each of the eight sample plants were measured separately and the average weight per plant was recorded.

Number of marketable fruits per plant (no.): Marketable fruits at each harvest were sorted out and counted. Those fruits that were clean, healthy, normal shape and were considered as the indices for tomato physical quality were separated.

Number of unmarketable fruits per plant (no): The unmarketable fruits at each harvest were also sorted out, as those with symptoms of disease, damaged fruits, misshapen, un uniform ripened fruits and immature were counted and recorded.

Marketable fruit yield kg/ha: The weight of marketable fruits harvested from the sample plants were taken at each harvest.

Unmarketable fruit yield per plot (tones/ha): The weight of unmarketable fruits harvested from the sample plants were also taken at each harvest.

Pericarp Thickness (mm): The pericarp thickness was measured using calliper. Three fruits were randomly selected at red ripe stage from the sample plants according to sizes. Then the fruits were cut into two with a knife and the thickness was measured after removing the flesh.

Fruit length and diameter (cm): Five fruits were selected randomly from the sample plants, the length and diameter of each fruit was measured using a calliper. The fruit shape index was calculated from the ratio fruits length to fruit diameter

Fruit shape: A tomato shape descriptor with the following rating scale was used: Flattened (oblate), 2 = Slightly flattened, 3 = Rounded, 4 = High rounded, 5 = Heart-shaped, 6 =Cylindrical (long oblong), 7 = plum shaped (ECPGR, 2008).

pH: The juice of the tomato was extracted by a manual extractor and sieved to remove the seeds and the solid particles. A pH meter was used to test the pH of the fruit juice.

Titratable acidity (%): From the juice of the randomly selected fruits (one millilitre juice) was drawn using a pipette into a beaker, three drops of phenolphttalein (colour indicator) was added into the juice in the beaker, then 0.1M NaOH was poured into a burette to zero mark, sodium hydroxide was ran into the solution gradually; while observing the colour change from colourless to pink. The amount of base (NaOH) that changed the colour from colourless to pink was recorded. The result collected was expressed as percentage acid.

$$\textbf{TA = percentage acid} = \frac{\textbf{Titre X acid factor X 100}}{\textbf{10ml (juice)}}$$

Where:

Titre = Amount of base used to develop the pink colour

Acid factor = 0.0064 (citrus fruits)

10 ml = Tomato juice

Source: OECD (2005)

Total soluble solids (^{o}Brix): The juice from the sample fruits was used to test the TSS by means of a hand-held refractometer. The refractometer was calibrated using distilled water to read accurately at a fixed temperature of 20^0C. Two drops of distilled water was placed on a prism surface and a tissue paper was used to clean the distilled water. The eyepiece of the refractometer was focused towards the light to observe the demarcation line between the light and the dark regions across the vertical scale, which gives the percentage soluble solids reading. As the demarcation was observed, a drop of juice was placed on the prism to read the percentage soluble solid.

Sugar to Acid Ratio (%): It was determined by dividing the result obtained from the total soluble solid by Titratable acidity of fruits (percentage of acid) and recorded.

$$\textbf{Sugar-acid ratio} = \frac{\text{TSS } (^0\textbf{ Brix })\textbf{x 100}}{\textbf{Percentage of acid}}$$

Source: OECD, (2005)

Dry matter content of fruits, stems and roots (g): Four plants from the sample plants from each plot were harvested. Individual plant with its two fruits root and stems were weighed as fresh weight. Next, the stem and the fruits were chopped into smaller pieces for easy drying. In order to reduce the moisture content, the samples were sundried for ten days, then taken to the laboratory for further drying in a micro oven. The fruits stem and root samples were in the micro-oven at 105^0C for four hours. After the four hours, the sample were removed and weighed; then returned them to the oven, left for 30 minutes, removed again and weighed. This process continued until the values of two different weight attained remain constant. This indicates that, the sample has dried.

Disease and pest incidence: Incidence of disease is the rate at which new cases occurred in a population during a specified period.

The number of plants in each plot that were affected by the following diseases; Late blight (*Pytophthora infestans*) and fruit rot. The number of plants affected by birds and physiological disorder (sun burn and blossom end rot) were counted and recorded.

$$\text{Disease Incidence (DI \%)} = \frac{\text{Number of infected plants x 100}}{\text{Total number of plants observed}}$$

Source: Wikipedia (2007).

Cost and return: The cost of stakes, string, construction and labour cost were recorded. These were compared with money accrued from the sales of tomatoes, and the differences were taken to show the feasibility of using staking in tomato production.

3.7. Data Analysis

The data collected were subjected to analysis of variance (ANOVA) and correlation; where treatments were found significant, the mean differences were tested following the LSD (Least Significant Differences) test procedure. The Statistical Analysis software (SAS), version 9.1.

4. RESULTS AND DISCUSSION

4.1. Interaction Effect of Staking Methods and Varieties on Growth Attribute of Indeterminate Tomato

4.1.1. Plant height

The analyses of variance indicates that, interaction effect between varieties and the staking methods was highly significant ($P<0.01$) (Appendix Table 1). The result in table 4 showed that, the highest plant height was obtained from the treatment combinations of Marglobe variety with single post staking (158.69 cm), followed by Marglobe with single string staking (103.55 cm), French type staking (89.95cm) and with non- staking (88.19 cm) which are statistically similar; whereas the shortest plant height was recorded from combination of Miya and Metadel with non-staking method (46.29 cm and 60.59 cm), respectively. Valenzuela *et al.,* (1993) obtained the highest plant height as 50.2 cm and the lowest height was 43.6 cm from an experiment conducted on Vegetable Cultivar Trials in Hawaii.

The tallest plant height observed from Marglobe with single post and single string staking could be that almost every leaf of the plant received sunlight for more nutrient for photosynthesis since the plants were upright, supported by staking than the control plants that were left compacted on the ground. In terms of French type staking, the plants were supported side by side, therefore, the leaves were somehow compacted at the center (in-between the plants) therefore, did not allow free penetration of light and air. The variations among the three varieties, however, could be attributed to inherent varietal differences (Ashrafuzzma *et al.*, 2010).

4.1.2. Number of primary branches

The interaction effect among staking methods and varieties on the number of primary branches showed a very highly significant difference ($P<0.001$) (Appendix Table 1). The highest number of primary branches was registered from Marglobe variety with single string staking (7.08), followed by Miya with single string staking (6.75) and single post staking (6.71) but they were statistically similar (Table 4). However, the least number of primary branches was recorded from Marglobe with French type staking (5.74). indeterminate tomato varieties have many widely spaced branches as reported by (Reiner, 2004) It is possible that the number of primary branches were influenced by staking methods, as the plants grows and received more energy from sunlight, the more branches developed. Although Ashrafuzzaman *et al*. (2010) reported that, difference in the number of primary branches could be due to genetically factors.

Table 4. Interaction effect of Staking Methods and Variety on Plant height (cm) and Number of Primary Branches

Variety	Staking	Plant height (cm)	Number of primary branches
Marglobe	Non-staking	88.19[bc]	6.37[b]
	Single post staking	158.69[a]	6.33[b]
	Single string staking	103.55[b]	7.08[a]
	French type staking	89.95b[c]	5.74[c]
Metadel	Non-staking	60.59[ef]	6.29[b]
	Single post staking	68.77[de]	6.46[b]
	Single string staking	74.40[cde]	6.25[bc]
	French type staking	65.69[de]	6.25[bc]
Miya	Non-staking	46.29[f]	6.46[b]
	Single post staking	72.24[cde]	6.71[ab]
	Single string staking	71.01[cde]	6.75[ab]
	French type staking	81.94[cd]	6.46[b]
LSD 5%		19.08	0.51
CV (%)		4.16	4.73

Values having common letter (s) in a column do not differ significantly at 5% level.

4.1.3. Numbers of flower per cluster

The analysis of variance showed no interaction effect between varieties and staking methods on the number of flower per cluster P>0.05 (Appendix Table 1). However, there was a very highly significant difference among the staking methods and varieties (P<0.001). However, The means separation among the staking methods indicated that, the French type staking, single post staking and single string staking were statistically similar. But the French type staking gave the highest number of flower per plant (73.62) compared to the non-staking method that gave the least number of flowers as (58.65) (Table 5).

In terms of varieties, Miya variety had the maximum number of flowers (75.26) followed by Metadel and Marglobe varieties (63.72 and 63.73). The results further supported by the positive and very highly significant correlation between the number of flower per cluster with fruit set per cluster (r= 0.95***). Probably the staking methods might have influenced the plant height as the plants were raised and supported by stakes, could allowed the leaves to get access to light for photosynthesis, in turn favored the number of branches and trusses where by produced more flowers.

4.1.4. Numbers of fruit set per cluster

There was a very significant difference among the staking methods ($P< 0.001$) and varieties ($P< 0.0001$) with no interaction effect between the staking methods and the varieties on the number of fruit set per cluster, (Appendix Table 1). However, that means separation among the staking methods indicated that, the French type staking, single post staking and single string staking were statistically similar. But the French type staking gave the highest number of flower per plant (73.62) compared to the non-staking method that gave the least number of flowers as (58.65).

In terms of varieties, Miya variety had the maximum number of flowers (75.26) followed by Metadel and Marglobe varieties that are statistically similar (63.72 and 63.73).

The results further supported by the positive and very highly significant correlation between the number of flower per cluster with fruit set per cluster (r= 0.950 ***). Probably the staking methods might have influenced the plant height as the plants were raised and supported by stakes, could allowed the leaves to get access to light for photosynthesis, in turn favored the number of branches and trusses where by produced more flowers.

Table 5. Effects of staking methods and varieties on numbers of flowers and numbers of fruit set per cluster

Staking	No. flower per cluster	No. fruit set per cluster
Non-staking	58.65[c]	45.27[b]
Single post staking	70.67[ab]	59.34[a]
Single string staking	67.3[ab]	56.58[a]
French type staking	73.62[a]	61.53[a]
LSD (5%)	4.02	7.69
Variety		
Marglobe	63.73[b]	49.45[b]
Metadel	63.72[b]	53.73[b]
Miya	75.26[a]	63.86[a]
LSD (5%)	3.48	6.66
CV (%)	6.08	14.13

Values having common letter (s) in a column do not differ significantly at 5% level.

4.2. Effect of Staking Methods and Varieties on Yield Attribute of Indeterminate Tomato

4. 2.1. Number of marketable fruits per plant

The interaction between the staking methods and the variety on the number of marketable fruits per plant was very highly significant (P< 0.001) (Appendix Table 2). The highest number of marketable fruits was obtained from Miya variety with French type staking (36.96) followed by Miya with single string staking (28.62), which did not significantly differ with single post staking (25.99), Marglobe, Metadel and Miya with non-staking methods gave the lowest number of marketable fruits per plant 13.79, 11.49 and 18.54, respectively,

Which could be attributed to increase in number of unmarketable fruits which is supported by the negative and significant correlation between the number of unmarketable and marketable fruits (r=-0.68**).

The variation in the number of marketable fruits among the staking methods could be due to the incidence of late blight, fruit rot diseases that occurred as a result of high soil moisture caused by frequent rainfall which seriously affected the fruits of the non staked plots. In addition, birds significantly affected the fruits at pink and red ripe stages in all the staking methods as well as the non- staked control, agreement with Birhanu and Talihun (2010) who found that small animals and birds have interest in tomato. Miya variety with all the staking methods was highly affected by blossom end rot which might have suffered from Calcium deficiency (Nzanza, 2006).

Defoliation caused by late blight (*Phytophotora infestans*) disease has led to exposure of fruits to sunlight that rendered the fruits to sun scorched, and this is in agreement with the work of Ariyarathne (1989) and Maboko, (2006) who reported that, significantly high marketable from bench method (41.89 tons/ha), and triangle (37.88 tons/ha) method than the non-staked control that yielded the lowest (22.66 tons/ha).

4.2,2. Number of unmarketable fruits per plant

There was interaction effect between varieties and the staking methods that showed a very highly significant difference (P <0.001) on the number of unmarketable fruits per plant (Appendix Table 2). The highest number of unmarketable fruits was obtained from Metadel with non-staking (29.75), followed by Miya with non- staking (21.66), Marglobe with non- staking (20.92) which were statistically similar (Table 6). The number of unmarketable fruits was recorded from Miya with French type (13.17), with single string staking (14.17) and Marglobe with single string staking (15.75) and they were statistically similar. These findings are consonance with (Kader and Morris, 1976; FAO, 1988; Ariyarathne, 1989; Lemma, 2002) who observed more of unmarketable fruits from non-staked plots that were caused by rotting of fruits from moist soil.
The unmarketable fruits recorded from staked methods, were mostly damaged from birds and physiological disorder. However, staking could be important cultural practices for tomato production to reduce losses as suggested by the above mentioned researchers.

4.2.3. Total number of fruits per plant

The analysis of variance showed interaction effect between the staking methods and varieties on the total number of fruit high significant (P< 0.001), (Appendix Table 3). Miya variety with French type staking gave the highest number of fruits (50.13) but that obtained from Miya with single post staking (43.36), and single string (42.79) staking method was low and did not differ from non- staking control methods. (40.21). However, the lowest average number of fruits were recorded from Marglobe variety with single post (33.96) and single string staking methods

(33.79) and with non-staking method (34.71), which were statistically similar. The low total number of fruits recorded from Marglobe variety which all the treatment mentioned could be genetically influenced.

Table 6. Interactions effect of staking methods and variety on the number of marketable fruits, number of unmarketable fruits, total number of fruits per plant

Variety	Staking	Number of Marketable Fruit/ plant	Number of unmarketable Fruits/ plant	Total Number of Fruits
Marglobe	Non-staking	13.79[f]	20.92[b]	34.71[d]
	Single post staking	19.67[e]	14.29d[ef]	33.96[d]
	Single string staking	18.04[e]	15.75d[ef]	33.79[d]
	French type staking	20.11[de]	19.5b[c]	39.87[bc]
Metadel	Non-staking	11.49[f]	29.75[a]	41.24[b]
	Single post staking	20.21[de]	19.08[bc]	39.29[bc]
	Single string staking	3.57[cd]	17.25[cde]	40.82[b]
	French type staking	18.38[e]	17.37[cd]	35.75[cd]
Miya	Non-staking	18.54[e]	21.66[b]	40.21[b]
	Single post staking	25.99[bc]	17.37[cd]	43.36[b]
	Single string staking	28.62[b]	14.17[ef]	42.79[b]
	French type staking	36.96[a]	13.17[f]	50.13[a]
LSD 5%		3.63	3.10	4.34
CV (%)		10.7	9.96	6.46

Figures having common letters (s) in the same column do not differ significantly at 5%.

4.2.4. Marketable yield per plant (tons/ha)

There was highly significant ($P<0.001$) interaction effect between varieties and the staking methods on the marketable fruit yield, (Appendix Table 2). The result in this table showed that, the highest yield was obtained from combination of Metadel variety with French type staking (83.63 tons/ha), followed by Miya variety with French type staking methods (75.20 tons/ha) and Marglobe with French type staking (72.14 tons/ha), though they were statistically similar. The lowest yield was recorded from non- staked method with Miya (30.60 tons/ha). FAO (1988) and NGA (2009) indicated that staking protects tomato fruits from disease and provides good quality tomatoes. Staking can increase fruit yield (Kader and Morris, 1976). The Godfrey-Sam-Aggrey *et al*. (1985) reported that, staking gave an increased yield of 6.5 tons from Heinz 1350.

4.2.5. Unmarketable Fruit Yield (tons/ha)

The interaction effect between variety and staking method was highly significant on the unmarketable of fruit yield (P<0 .001) (Appendix Table 2). Result in table 6 showed that Metadel variety gave the highest yield of unmarketable fruits from non staked control method (83.31 tones/ha) followed by Marglobe with non-staked method (50.37 tons/ha) non- staked with Miya (45.99 tons/ha) Marglobe with French type staking (40.64 tons/ha) but statistically similar. Miya with French type staking had low unmarketable fruit yield (18.99 tons/ha). Ariyarathne (1989) recorded low yield of 17.52 tons/ha from non-staked control methods compared to the staked (87.88 tons/ha) and (41.89 tons/ha) from bench method. Similarly, Lemma (2002) reported the highest yields of 58.3 tons/ha and 57.3 tons/ha from staked tomato plants compared to 39.9 tons/ha and 33.4 tons/ha from un-staked plants. The result indicated that, staking might have protected the fruits from being damaged. Egun, (2007) also reported the marketable leaf yield 500.0 to 500.5 g from staked plants and 498.3–499.5 g from un-staked plants (pumpkin). Diseases and physiological disorder mostly affected non-staked plants, whereas birds and unidentified animals widely affected both the staked and un-staked plants agreement with the works of Kader and Morris (1976); Ariyarathne, (1989); FAO (1988) and Lemma (2002).

4.2.6 Total fruit yield per plant (tons/ha)

The interaction between staking methods and variety was highly significant (P < 0.001) (Appendix Table 2). The result in Table 6 showed that, the highest total fruit yield was obtained from Metadel with non-staking (137.97 tons/ha), followed by Metadel and Marglobe both with French type staking (122.29 tons/ha) and (119.78 tons/ha), though they are statistically similar. However, the lowest total fruit yield was observed from Miya with non-staking (76.67 tons/ha), single string staking (1.80 tons/ha) and French type staking (1.97 tons/ha). The yield of 6 tons/ha was recorded from staking methods by Godfrey-Sam-Aggrey *et al*. (1985). Meaza *et al*. (2007) recorded poor yield of tomato and suggested that, it could be due to excessive nitrogen. However, the result obtained from this study could be due to defects fruits (fruits affected by disease, birds misshapen, cracking etc) recorded during the experiment.

Table 7. Interactions effect of staking methods and variety on marketable and unmarketable fruit yield and total yield (tons/ha)

Variety	Staking	Marketable Fruit Yield (tons/ha)	Unmarketable Fruit Yield (tons/ha)	Total Yield (tons/ha)
Marglobe	Non-staking	62.18cde	50.37b	112.56cd
	Single post staking	62.82cd	33.64e	96.47fg
	Single string staking	69.36bc	39.06cd	108.42de
	French type staking	72.14b	40.64b	119.78bc
Metadel	Non-staking	54.66f	83.31a	137.97a
	Single post staking	61.79def	40.99c	102.78ef
	Single string staking	68.12bcd	35.60de	103.72ef
	French type staking	83.63a	38.66cd	122.29b
Miya	Non-staking	30.69g	45.99b	76.69i
	Single post staking	75.20b	34.39de	109.59de
	Single string staking	54.92ef	31.07e	85.99h
	French type staking	75.12b	18.99f	94.12g
LSD 5%		7.30	4.92	8.02
CV (%)		6.71	6.98	4.47

Figures having common letters (s) in the same column do not differ significantly at 5%.

4.2.7. Fruit length (cm)

Interaction of staking methods and variety were very highly significant (P< 0.001) in fruit length (Appendix Table 3). The results in Table 7 showed that, the highest fruit length was recorded from Marglobe with single string staking, followed by Metadel with French type staking (6.13 cm) and low fruit length was obtained from Miya with single post (5.23 cm) and single string staking method (4.56 cm), and non- staking control (4.50 cm).

Table 8. Interaction effects of staking methods and variety on fruit length, fruit diameter and fruit shape index

Variety	Staking	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Shape Index
Marglobe	Non-staking	5.53^{cd}	4.43^{bc}	1.26^{bc}
	Single post staking	5.60^{cd}	4.23^{c}	1.32^{b}
	Single string staking	6.66^{a}	4.16^{c}	1.60^{a}

	French type staking	5.73bc	4.73ab	1.21bcd
Metadel	Non-staking	5.43cd	5.13a	1.06ef
	Single post staking	5.43cd	5.01a	1.06def
	Single string staking	5.76bc	5.06a	1.14cde
	French type staking	6.13b	4.83a	1.27bc
Miya	Non-staking	4.50e	5.10a	0.88g
	Single post staking	5.23d	4.23c	1.23bc
	Single string staking	4.56e	4.80ab	0.95fg
	French type staking	4.76e	4.80ab	1.00efg
LSD 5%		0.42	0.47	0.15
CV (%)		4.59	5.90	7.60

Values having common letter (s) in a column do not differ significantly at 5% level.

4.2.8 Fruit diameter (cm)

The interaction of staking methods and variety was also significant on fruit diameter (P< 0.05). Metadel variety with all the staking methods and all the staking methods except the single post staking that gave the high fruit diameter but were statistically similar Table 7. Marglobe varieties with all the staking methods except with French type of staking had low fruit diameters, although there is variation on Miya variety with non staking that gave high fruit diameter similar with Metadel with other staking methods.

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4.2.9. Fruit shape index

The interaction effect between the staking methods and variety was highly significant (P< 0.01) (Appendix Table 3). The highest fruit shape index was observed from Marglobe variety with single string staking (1.60) followed by Marglobe with single post staking (1.32) and Metadel with French type staking method (1.27cm) and Miya with single post staking, though they are statistically similar. However, the low fruit shape indices were obtained from Miya with French type staking (1.0) and with single string method. Numerous loci controls fruit shape (Brewer *et al.,* 2006) .The differences in shape index could be genetically potential of the parent plants.

4.2. 10. Pericarp thickness (mm)

The interaction effect between the staking method and variety and the main effect of staking methods were non-significant on pericarp thickness, but the variety were highly significant (P<0.001) (Appendix Table 3). Miya gave the thickest pericarp, followed by Marglobe and Metadel which are statistically similar. This implies that, staking methods had no effect on the pericarp thickness of the tomato varieties. The differences in the pericarp thickness could be genetic.

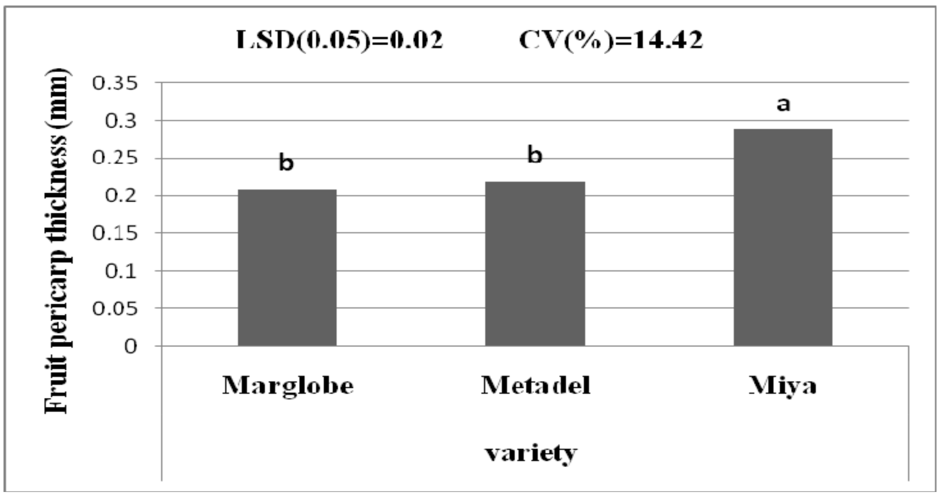

Figure 1. Response of varieties to fruit pericarp thickness

4.2.11. Root dry matter content per plant

The interaction between staking methods and varieties on root dry matter was very highly significant (P< 0.001) (Appendix Table 5). Miya variety irrespective of staking methods gave high dry matter ranging from 18.83 to20.70 g but they were statistically similar (Table 9). Low root dry matter content was observed from Metadel variety with all the staking methods being statistically similar. The interaction between variety and staking methods in root dry matter seems to be due to high root dry matter in single post and single string staked in Marglobe, but low root dry matter in un- staked and French type staked treatment of Marglobe. The root dry matter seems to be lower than that of fruits and stems, because the partition of the nutrient was mainly to fruits and branches. Fruits are the strongest sinks for assimilate in tomato; whereas stems and roots are weaker sinks of assimilate Cockshull and Ho (1995).

4.2.12. Fruit dry matter per plant

Similarly, the interaction between the staking methods and the varieties on fruit dry matter was highly significant (P< 0.001) (Appendix Table 5). Results in table 9 showed that, the highest fruit dry matter was obtained from Marglobe with French type staking (52.27 g) followed by Miya with single post staking (43.58 g), Marglobe with non-staking (41.55 g) and with single string staking (40.25 g) though the three treatment are statistically similar. The least fruit dry matter was obtained from Metadel (16.40 g) and Miya (17.11) both with non-staking. A study by Heuvelink, (2010) revealed 58–60% of dry matter was found in fruits for control plants, whereas for both double-shoot treatments was 43% (Heuvelink, 2010). Cockshull and Ho (1995) reported that, fruit are the strongest sinks for assimilate in tomato plant. In this study, the non- staking showed low fruits dry matter as (17.11- 41.55 g) but the staking methods had similar dry matter content of (43.58-52.27 g) compared to the previous works. This work seems to agree with Heuvelink (2010).

4.2.13. Stem dry matter per plant

Interaction between the staking methods and the varieties on stem dry matter was very highly significant (P< 0.001) (Appendix Table 5). Metadel with single post staking had the highest stem dry matter (79.37 g) followed by Marglobe with French type staking (61.68 g) with non-staking method (61.01 g) and statistically similar. The lowest stem dry matter was observed from Marglobe with single string staking (29.23 g) and Miya with non-staking (28.75 g), with single post staking (30.19 g) with no statistically difference among them. The difference between the fruit and stem dry matter could be influenced by the size of the fruits at the time they were harvested. They were harvested after the sixth harvest when there was less fruits to take the carbohydrate from the source.

Table 9. Interaction effect of staking methods and variety on root dry matter, fruit dry matter and stem dry matter

Variety	Staking	Root Dry Matter (g/plant)	Fruit Dry Matter (g/plant)	Stem Dry Matter (g/plant)
Marglobe	Non-staking	10.17[b]	41.55[b]	61.01[b]
	Single post staking	17.19[a]	32.62[ef]	50.71[c]
	Single string staking	19.60[a]	40.24[bc]	29.23[e]
	French type staking	13.27[b]	52.27[a]	61.68[b]
Metadel	Non-staking	11.04[b]	16.40[g]	39.59[d]
	Single post staking	11.89[b]	39.56[bcd]	79.37[a]
	Single string staking	12.52[b]	34.66[de]	45.25[cd]
	French type staking	13.06[b]	29.11[g]	42.32[d]
Miya	Non-staking	20.70[a]	17.11[g]	28.75[e]
	Single post staking	20.70[a]	43.58[b]	30.19[e]
	Single string staking	18.83[a]	35.75[cde]	42.19[d]
	French type staking	18.50[a]	32.51[ef]	48.46[c]
LSD 5%		3.81	5.04	6.10
CV (%)		14.42	8.60	7.73

Values having common letter (s) in a column do not differ significantly at 5% level.

4.3. Effect of Staking Methods and Variety on Quality Response Variables

4.3.1. Titratable acidity

The combined effects of variety and staking method showed significant interaction effect ($P < 0.001$) on titratable acidity (Appendix Table 4). The varieties Metadel and Marglobe with non-staking method had higt titrable acidity (1.02% and 1.0%), followed by Metadel with single post and single string staking methods that had the same titratable acidity (0.98%) and Marglobe with French type staking (0.96%) which were statistically similar Table 8. However, the lowest percentage of acid was obtained from Marglobe with single string staking (0.53%). Wahundeniya *et al.* (2006) reported the percentage of acid ranges from 0.78 - 0.97 of some varieties of tomato tested. The high acid content was recorded from Metadel and Marglobe especially from the control plots (without staking) than Miya variety. The lesser the water content the more sour is the fruit (Davies and Winsor, 1969). However, the acidity content of tomato dependent on the stage of harvest and the consumer preference, some people preferred fruits with high acidity while others like fruits with less acid, high sugar and flavor.

4.3.2. Total Soluble Solid (^{0} Brix)

The analysis of variance on TSS showed that the interaction between variety and staking methods was significant ($p<0.05$) (Appendix Table 4). Marglobe irrespective of the staking treatment gave high TSS ranging from 3.56 to 3.80, followed by Miya variety with non- staking (3.46%), Metadel with non-staking (3.43%) and with French staking method (3.405%), with no significant different among the three treatment. However, the least percentage was obtained from Metadel with single post staking (3.10%) and Miya with French type staking (3.0%). Water deficit was found to increase fruit soluble solid level (Mitchell and Shennan, 1991). Maboko, (2006) confirmed that, frequency of water supply affect yield and fruit quality. In addition, increase in rate of irrigation can lead to a reduction in soluble sugar. Wahundeniya *et al*. (2006) reported TSS found, ranges from 4.92- 5.07 ^{0}Brix. MARD (2005) reported the TSS recorded from Miya was 4.0% and that of Metadel was 4.4%. However, there is no significant difference between the TSS found among the varieties tested (Marglobe, Metadel and Miya) with all the staking methods. This implies that, staking methods influenced the TSS.

4.3.3. Sugar acid ratio

The interaction between staking methods and varieties on sugar acid ratio showed a very highly significant $p<0.001$ (Appendix Table 4). Miya with non- staking and French type staking gave high sugar to acid ratio of (4.86%) and (4.66%) respectively but the latter did not significantly differ from single string staking (4.53%) and single post staking methods of the same variety (Table 8). However, the minimum sugar acid raio was obtained from Metadel with single post and single string methods (3.13%).

4.3.4. pH

The interaction between the staking methods and the varieties on pH was highly significant ($P < 0.001$) (Appendix Table 4) . The result in table 8 revealed that, Marglobe with French type staking method gave high pH of (4.86) followed by Miya with single post staking (4.63) though they are statistically similar. The low pH was recorded from Marglobe with non-staking method (4.20) and with single post staking (4.2) but only significant different from single post and single string staking, the same variety and non-staked Miya.. Among the researchers, Nzanza (2006) recorded the pH of two varieties as 4.16 and 4.08 from research work conducted on yield and quality of tomato as influenced by Ca, Mg and K nutrition. However, Wahundeniya *et al.* (2006) found no significant different in pH among the varieties of tomato grown under controlled environment. MARD (2005) reported the pH of Miya as 4.5 and that of Metadel 4.7 somehow higher than the results of the present study.

Table 10. Interaction effects of staking methods and variety on titratable acidity (%), total soluble solid (^{o}brix), sugar acid ratio (%) and pH

Variety	Staking	Titratable Acidity	Total Soluble Solid	Sugar acid ratio	pH
Marglobe	Non-staking	1.00^{a}	3.70^{ab}	3.46^{ef}	4.20^{d}
	Single post staking	0.91^{c}	3.60^{abc}	4.10^{d}	4.2^{d}
	Single string staking	0.53^{e}	3.56^{abc}	4.40^{c}	4.53^{bc}
	French type staking	0.96^{abc}	3.80^{a}	3.26^{fg}	4.86^{a}
Metadel	Non-staking	1.02^{a}	3.43^{cd}	3.53^{e}	4.46^{bcd}
	Single post staking	0.98^{ab}	3.10^{e}	3.13^{g}	4.26^{cd}
	Single string staking	0.98^{ab}	3.06^{e}	3.13^{g}	4.40^{bcd}
`	French type staking	0.92^{bc}	3.40^{cd}	3.66^{e}	4.23^{cd}
Miya	Non-staking	0.74^{d}	3.46^{c}	4.86^{a}	4.36^{bcd}

	Single post staking	0.74^{d}	3.10^{e}	4.50^{bc}	4.63^{ab}
	Single string staking	0.74^{d}	3.20^{de}	4.53^{bc}	4.40^{bcd}
	French type staking	0.70^{d}	3.00^{e}	4.66^{ab}	4.23^{cd}
LSD 5%		0.06	0.24	0.26	0.31
CV (%)		4.34	4.22	3.92	4.16

Values having common letter (s) in a column do not differ significantly at 5% level.

4.4. Disease incidence, physiological disorder and bird attack

The analysis of variance indicated that, the interaction between the staking methods and variety and among the varieties were not significant P<0.001 on late blight (LB), but very highly significant on staking methods P< 0.001 (Appendix Table 6). However, the mean separation among the staking methods revealed that, the non- staking methods had the maximum LB attack of 1.34%, French type staking 1.10% and single post staking 0.94% but statistically similar, but the minimum infection was recorded from single string staking 0.54%. The variations of LB attack recorded from the staking methods especially the French type staking that supported the plants side by side and couple with the high density of plants might have hindered free penetration of air and light to dry the moisture after rain and high humidity.

Fruits produced on the controlled plots were in contact with wet soil that caused high LB incidence than the staking methods. This implies that, staking is necessary for tomato Fig1.

The interaction between the staking methods and variety on blossom end rot were very significant (P< 0.001). Miya and Metadel with non staking method had high late blight infection Table 10, they were significantly similar. The low infection was recorded from Marglobe and Metadel with single post and single string staking methods and Metadel with. The marketable fruit yield was negatively affected by BER and the fruits were regarded as unmarketable. In conclusion, since Miya with all the staking methods were affected by BER, indicating that, it was susceptible to BER due to Ca deficiency (Nzanza, 2006)

Similarly, interaction between the staking methods and variety on fruit rot was very significant (P< 0.001) (Appendix Table 6) All the three varieties had high percentage of fruit rot when they are not staked Table 10. All the three staking methods with Marglobe, Metadel and Miya had no rotted fruits.

In terms of birds incidence, the interaction between the staking methods and variety was very significant (P< 0.001) (Appendix Table 6). Birds incidence was high with all the varieties and staking methods. Small animal and birds fed more on Melkssa Marglobe than Melka Shola cultivar (Birhanu and Tilahun, 2010). But this study showed that, the small animals and birds were interested on all the cultivar used (Marglobe, Metadel and Miya). This means that, small animals and birds like tomato regardless of the cultivar.

The interaction between staking method and variety was very in sunburn highly significant p<0.001. Non-staked treatments of all the three varieties had high percentage of sunburn fruits, however, they were statistically similar (Table 10.) The least sunburn fruits were recorded from Marglobe with single post staking and single string staking, Miya with single post staking and French Type staking. The sunburn affected treatments combination were due to defoliation by Late blight (*Phytophthora infestans*) that led to the exposure of fruits to sun light. This could be because of lack of proper air and light penetration to reduce high humidity within the plants.
Saunyam and Knapp (2003) reported that, trellising resulted in better mite management, less disease incidence, less fruit rots and reduced damage in fruits that can result to profits. However, it could be recommended that French type staking method and single string staking could be used in Jimma condition if more spacing and less number of plants per row are used to allow free penetration of air after rainy, easy access of weeds and free movement.

Table 11. Interaction effect of variety and staking methods on the number blossom- end- rot, fruit rot, birds and sunburn

Variety	Staking	Blossom End rot	Fruit rot	Birds	Sun burn
Marglobe	Non-staking	0.53[e]	1.16[a]	14.88[a]	1.13[a]
	Single post staking	0.00[f]	0.00[c]	14.88[a]	0.00[d]
	Single string staking	0.00[f]	0.00[c]	14.88[a]	0.00[d]
	French type staking	0.00[f]	0.00[c]	13.88[a]	1.02[ab]

Metadel	Non-staking	1.25^{ab}	1.22^{a}	13.49^{a}	1.20^{a}
	Single post staking	0.00^{f}	0.00^{c}	16.27^{a}	0.70^{bc}
	Single string staking	0.00^{f}	0.14^{b}	14.88^{a}	0.00^{d}
	French type staking	1.11^{bc}	0.14^{b}	13.50^{a}	0.42^{c}
Miya	Non-staking	1.28^{a}	1.23^{a}	12.11^{a}	1.16^{a}
	Single post staking	0.81^{d}	0.00^{c}	13.49^{a}	0.00^{d}
	Single string staking	0.86^{d}	0.00^{c}	14.0^{a}	1.02^{ab}
	French type staking	1.05^{c}	0.00^{c}	14.55^{a}	0.00^{d}
LSD 5%		0.15	0.09	4.82	0.33
CV (%)		1.87	15.98	21.63	35.34

Values having common letter (s) in a column do not differ significantly at 5% level.

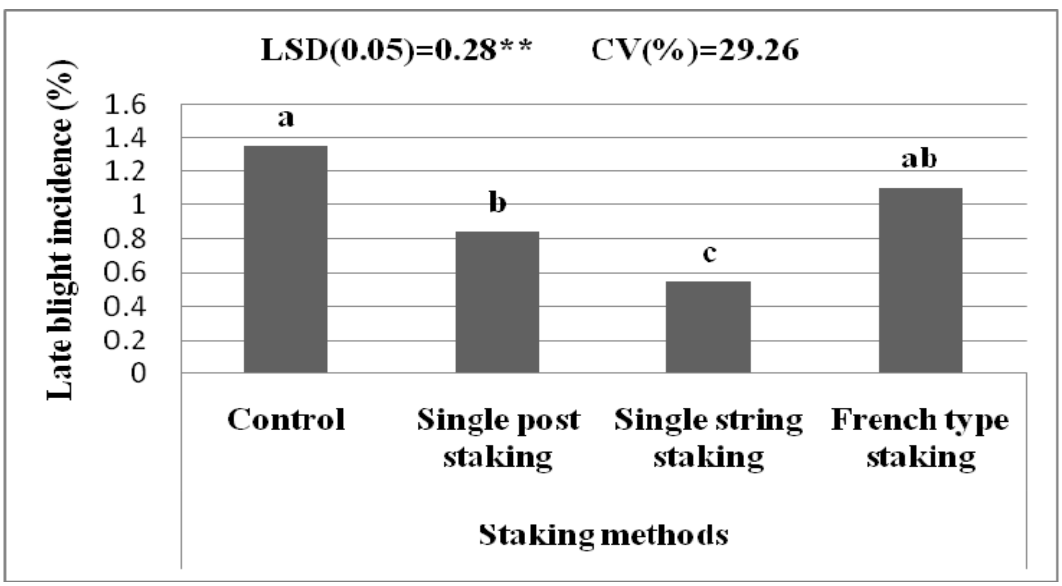

Figure 2. Effects of staking on late blight disease on tomato

4.5. Cost and returns of labor and materials for different staking methods

Fig 2 below showed the net profit of different staking methods. The net profit for different staking methods in Fig. 2 showed that, Metadel variety with French type staking gave the highest profits of about 301.54 Birr per plant. This was followed by single string staking (268.44 Birr) per plant. The non-staked treatment and Metadel on the other hand gave a profit of 197.14birr, which was not significantly higher than single post staking 193.94 Birr. A that time, a kilo of tomato was sold at 6 Birr, therefore, the income acrued from non-staking method amounted to 357.60 Birr, single post staking =336.60 Birr, single string staking 357.60 Birr and French type staking gave 365.60 Birr. This study suggests that French type and single string staking to farmers as the cheapest methods of staking tomato plants as reported by Ariyarathne, (1989), Saunyama and Knapp (2003) in their work on pruning and trellised that led to additional profits.

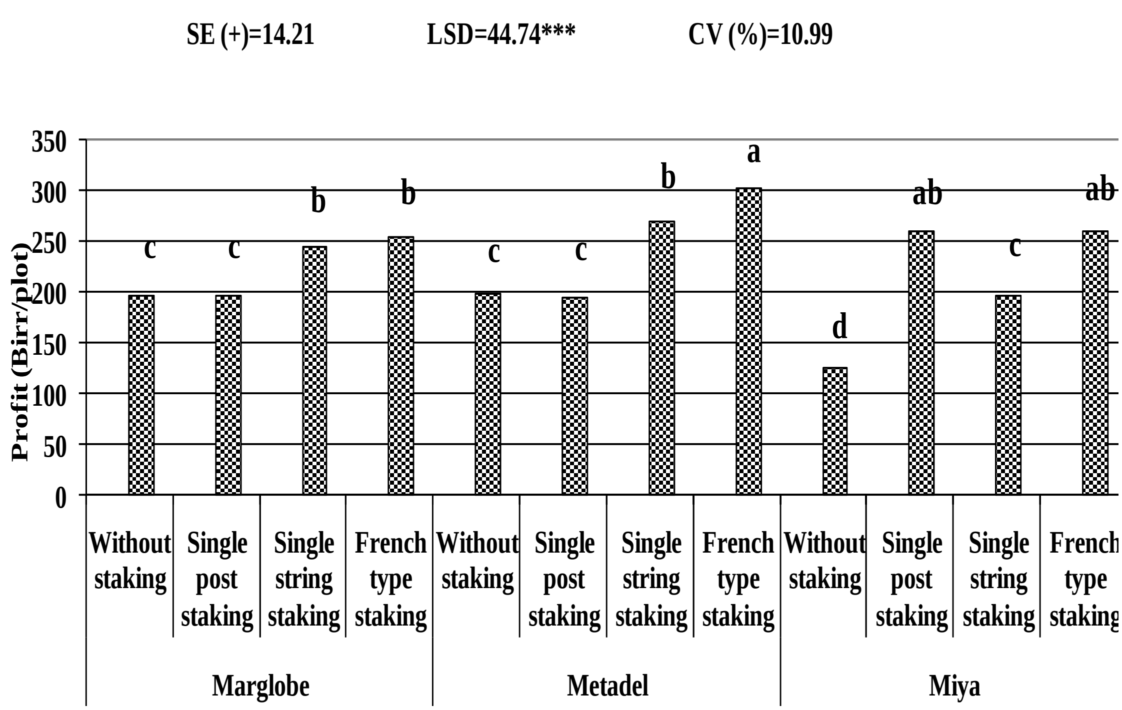

Fig 3: Cost and returns of different staking methods

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5. SUMMARY AND CONCLUSION

Disease and pests are the constraints of tomato producers all over the world including Ethiopia. A field study was conducted to study the effect of different staking methods on yield and quality of indeterminate tomato (*Lycopersicon esculentum* Mill) varieties under Jimma condition, in the experimental field of College of Agriculture and Veterinary Medicine, Jimma University. Miya, Marglobe and Metadel varieties were used while the staking methods were single post staking, single string staking, French type staking and the non- staking as the control. Data collected were subjected to Analysis of variance, means separation was conducted where mean of variety and, staking were found significant and no interaction and correlation coefficient was conducted among the parameters. The result showed that Miya variety had recorded significantly highest number of flowers than Marglobe and Metadel, both of which were not significantly different from one another.

The results were further supported by a strong positive correlation between the number of flower per cluster and fruit set per cluster (r= 0.95***), number of marketable fruits (r= 0.71 ***). There was significant difference in the number of fruits set per cluster due to variety and staking.

The interaction effect between the staking methods and varieties on the number of marketable fruits was very highly significant (P< 0.001). Similarly, the number of unmarketable fruit showed interaction effect between the staking methods and variety (p< 0.0001). However the number of fruits had a positive correlation with the number of marketable fruits (r =0.661**), but negatively correlation with the number of unmarketable fruits (r= -0.531**. Number of marketable fruits, therefore, was negatively correlated with the number of unmarketable fruits at (r = -0.679 ***). This implies that when the number of marketable fruits decreases, the number of unmarketable fruits increases. Similarly, the staking methods and varieties interacted significantly (p< 0001) on the number of unmarketable fruits yield. The number of marketable fruits was found to be negatively correlated with unmarketable fruit yield (r= -0.767***), and the number of unmarketable fruit was positively correlated with unmarketable fruit yield at (r = 0.904***). Plants gave a significant number of fruits set but was affected by too much rain that brought about fruit rot disease, and blossom end rot. Birds significantly destroyed the fruits which lowered the number of marketable fruits as well.

Cost and returns of different staking and labor showed that, French type staking gave the highest profit as 301.54 Birr followed by single string staking as 268.44 Birr, while the least profit was recorded from non-staking and single post staking 195.44- 195.78 Birr

In conclusion, the easiest method of reducing tomato disease incidence is by using French type and single string staking that cost less and gave high yield and good quality fruits than single post staking and non staked control. These could be suggested to farmers; however, conclusive recommendation should be based on results on repeated experiments. Moreover emphases should be given to staking methods need to be studied along with pruning under Jimma condition.

Rodents and birds that destroyed fruits at green and red ripe stage in Jimma need to be investigated.

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7. APPENDICES

APPENDIX A

Appendix A. Table 1. Mean square for Plant height , number of primary branch , number of flowers , number of fruit set and fruit set percentage

Source of variation	Df	Mean square			
		Plant Height	Primary branches	Number of Flowers/cluster	Number of Fruit set /cluster
Variety	2	721.838**	0.270^{NS}	532.609**	656.532**

Staking	3	185.665**	0.461**	377.456**	470.348**
Blocking	2	77.110	0.000	15.853	56.015
Variety x Staking	6	111.510**	0.268*	27.805^{NS}	92.308^{NS}
Error	22	127.044	0.092	16.932	61.977

Ns & ***= Non-significant and highly significant and very significant differences P< 0.05 or 0.01 probability levels.

Appendix A. Table 2. Mean square for Number of marketable fruits /plant, number of unmarketable fruits /plant, Total number of fruits /plant, marketable fruit yield, unmarketable fruit yield and total yield

Source of variation	Df	Mean square					
		Number of marketable fruits/plant	Number of unmarketable fruits /plant	Total number of fruits/plant	Marketable fruit yield	Unmarketable fruit yield	Total yield
Variety	2	1.991**	9.140**	220.12**	247.28**	879.64**	199.95**
Staking	3	193.534**	33.974**	20.608*	118.96**	133.81**	299.87**
Blocking	2	3.542	0.447	2.956	3.402	11.019	26.66
Variety x Staking	6	41.221**	23.668**	38.364**	343.36**	370.006**	708.83**
Error	22	4.600	3.357	6.569	18.61	8.457	22.440

* &* **= Significant and very highly significant at p<0.05 or 0.01 probability levels.

Appendix A Table 3. Mean square for Fruit length, fruit diameter, fruit shape index and pericarp thickness

Source of variation	Df	Mean square			
		Fruit Length	Fruit Diameter	Fruit set Index	Pericarp thickness
Variety	2	4.278**	1.236**	0.345**	0.0253**
Staking	3	0.429**	0.222^{NS}	0.047**	0.0011^{NS}
Blocking	2	0.105	0.043	0.002	0.0002
Variety x Staking	6	0.536**	0.210*	0.071**	0.00083^{NS}
Error	22	0.062	0.077	0.007	0.001

* &* *= Significant and highly significant at p<0.05 or 0.01 probability levels.

NS=Non significant at p<0.05 probability level.

Appendix A. Table 4. Mean square for Titratable acidity, total soluble solid, sugar acid ratio and potential hydrogen

Source of variation	Df	Mean square			
		Titratable Acid	Total soluble Solid	Sugar acid Ratio	pH
Variety	2	0.171**	0.808**	5.030**	0.035NS
Staking	3	0.039**	0.141**	5.0396NS	0.0244NS
Blocking	2	0.001	0.060	0.006	0.0170
Variety x Staking	6	0.041**	0.062*	0.557**	0.200**
Error	22	0.001	0.020	0.023	0.033

*&**= Significant and highly significant at p<0.05 & 0.01 probability levels. NS=Non significant at p<0.05 probability level.

Appendix A. Table 5. Mean square for root dry matter content, fruit dry matter content and stem dry matter content

Source of variation	Df	Mean square		
		Root dry matter content	Stem dry matter content	Fruit dry matter content
Variety	2	171.86**	758.68**	462.08**
Staking	3	17.61**	407.78**	373.69**
Blocking	2	0.64	3.92	11.640
Variety x Staking	6	20.37**	797.01**	245.57**
Error	22	5.06	12.97	8.87

*&**= Significant at p<0.05 & 0.01 probability levels.

Appendix A. Table 6. Mean square for incidence of diseases, physiological disorder and bird attack

Source of variation	Df	Mean squares				
		Late blight	Blossom -end –rot	Fruit rot	Birds	Sun burn
Blocks	2	0.22	0.002	0.006	5.050	0.100
Variety	2	0.01NS	2.256**	0.026**	68.86**	0.006NS
Staking	3	1.02***	1.206**	3.134**	33.70*	1.584**
Variety*staking	6	0.08NS	0.282**	0.007*	41.90**	0.776**
Error	22	0.08	0.21	0.003	8.10	0.038

*&**= Significant at p<0.05 & 0.01 probability levels.

Appendix A. Table 7. Correlation Coefficient (r) among the Characters in Tomato Cultivar grown at Jimma, 2009/ 2010

	PH	PB	NF	FS	NMFR	NUMFR	MFY	UMFY	FL	FD	TA	TS	DMR
PH	1.00												
PB	-0.35	1.00											
NF	0.016	0.01	1.00										
FS	-0.05	0.04	0.95**	1.00									
FSP	-0.23	0.08	-0.03	0.27									
NMF	-0.02	0.15	0.71**	0.66**	1.00								
NUMF	-0.41	-0.24	-0.59	-0.53	-0.67*	1.00							

MFY	0.21	-0.09	0.22	0.15	0.25	-0.39	1.00						
UMFY	-0.25	-0.21	- 0.69	-0.64	-0.76**	0.90**	-0.34	1.00					
FL	0.35	-0.05	-0.34	-0.397	-0.43	0.02	0.51**	0.12	1.00				
FD	-0.56*	-0.25	-0.05	0.00	-0.01	0.34	-0.29	0.25	-0.30	1.00			
FSI	0.55*	0.12	-0.24	-0.30	-0.29	-0.19	0.48*	0.04	0.85**	-0.74**			
TA	-0.03	-0.56**	-0.39	-0.41	-0.47	0.49*	0.01	0.50*	0.09	0.32	1.00		
TSS	0.30	-0.2	-0.41	-0.43	-0.57	0.24	-0.11	0.40	0.31	-0.23	0.18		
TS	-0.00	0.49**	0.47	0.47	0.43	-0.36	-0.27	-0.38	-0.43	-0.21	-0.82**	1.00	
pH	-0.14	0.10	0.15	0.11	-0.00	0.19	0.05	0.18	0.10	-0.10	-0.07	-0.016	
DMR	0.07	0.39	0.53**	0.54**	0.47	-0.46	-0.18	-0.48*	-0.30	-0.26	-0.80**	0 .82**	1.00
DMF	0.32	-0.07	0.22	0.17	0.22	-0.42	0.52*	-0.37	0.30	-0.46	-0.04	-0.260	-0.06
DMS	0.14	-0.35	-0.16	-0.207	-0.05	-0.02	0.17	-0.02	0.05	0.17	0.59**	-0.65**	-0.57*

*, ** Significant at 5% and 1% probability levels, respectively, values without asterisk are non-significant (P<0.05)

P H=Plant height, PB = Primary branches, NF= Number of flower, FS = Fruit set, FSP =Fruit set percentage, NMFR = Number of marketable fruit, NMFR = Number of marketable fruit, MFY= Marketable fruit yield, UMFY= Unmarketable fruit yield, FL = Fruit length, FD = Fruit diameter, FSI= Fruit set index, TA= Titable acidity, TSS= Total soluble solids, TS= Total Sugar , p H= Potential hydrogen, DMR= Dry matter content, DMF =Fruit dry matter, DMS = Stem dry matter.

APPENDIX B.

Appendix Plate 1: Single post staking

Appendix Plate 2: Single string staking

Appendix Plate 3: French type staking

Appendix Plate 4: Non-staking