EVALUATION OF ELITE HOT PEPPER VARIETIES (*Capsicum species*) FOR GROWTH, DRY POD YIELD AND QUALITY UNDER JIMMA CONDITION, SOUTH WEST ETHIOPIA

M.Sc. Thesis

Seleshi Delelegn

March, 2011

Jimma University

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Master of Science in Horticulture (Vegetable Science)

By

Seleshi Delelegn

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Jimma University

School of Graduate Studies

As Thesis research advisor, I hereby certify that I have read and evaluated this Thesis prepared under my guidance, by Seleshi Delelegn entitled "Evaluation of Elite Hot pepper varieties (*Capsicum species*) for growth, dry pod yield and quality under Jimma condition, South West Ethiopia". I recommend that it be submitted as fulfilling thesis requirement.

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As member of the board of examiners of the MSc. Thesis open Defense Examination, we certify that we have read and evaluated the Thesis prepared by Seleshi Delelegn 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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DEDICATION

I would like to dedicate this thesis to my wife Trualem Zerihun whose consistent encouragement and support has significantly contributed for successful completion of my graduate work.

I also dedicate this work to my lovely daughters, Fitsum Seleshi, Melat Seleshi and Adey Seleshi who always support me and are eager to see my success.

STATEMENT OF THE AUTHOR

I, Seleshi Delelegn, hereby declare that this thesis is my work and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at the Jimma University College of Agriculture and Veterinary Medicine and is deposited in the University's Library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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Name: Seleshi Delelegn Signature --------------------

Place: Jimma University

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BIOGRAPHICAL SCKETCH

The author, Seleshi Delelegn, was born in Oromia National Regional state, West Hararghe Zone, Dobba Woreda on November 12, 1963. He attended his elementary school at the same woreda and junior secondary school at Hirna from 1969 to 1976. He attended his high-school education at Chiro(the then Asebeteferi) senior secondary school from 1977 to 1980. After the completion of his high school education, he joined the then Ambo Junior College of Agriculture, now Ambo University and graduated with Diploma in General Agriculture in 1983.

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LIST OF ABBREVIATIONS

UADC	Uganda Agricultural Development Center
ARC	Agricultural Research Center
BOPEDORS	Bureau of Planning and Economic Development of Oromia Regional State
AVRDC	Asian Vegetable Research Development Center
CSA	Central Statistical Authority
EARO	Ethiopian Agricultural Research Organization
EEPA	Ethiopian Export Promotion Agency
ESEF	Ethiopian Spice Extracting Factory
FYM	Farm Yard Manure
GDP	Gross Domestic Product
IBPGR	International Board for Plant Genetic Resource
IPM	Integrated Pest Management
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
MoA	Ministry of Agriculture
JICA	Japan International Cooperation agency
SAS	Statistical Analysis Software

Evaluation of Elite Hot Pepper Varieties (*Capsicum species*) for Growth, Dry Pod Yield and Quality Under Jimma Condition, South West Ethiopia.

ABSTRACT

A field experiment was conducted at two locations under Jimma condition, to investigate the performance of different varieties of hot pepper for growth, dry pod yield and quality, thereby, to recommend best adapting and high yielding variety (varieties) for the farmers in the study area. The study was conducted from October, 2009, to March, 2010, at JUCAVM experimental field and Seka Chokorsa woreda (Kechema nursery site) under irrigated condition using nine hot pepper varieties (Mareko Fana,Bako Local, Melka Zala, Weldele, Melka Shote, Oda Haro, Dube Medium, Dube Short) and one local (Gojeb Local) as a control. The experiment consisted of two factors (location and variety) and was laid out in a split plot arrangement in a randomized complete block design with three replications. The result of the study showed significant interactions between location and varieties on days to 50% flowering, days to first harvest, mean number of flowers per plant, canopy diameter, mean number of branches (primary, secondary and territory), shoot and root dry weight (g); number of fruit per plant, number of seed per fruit, mean seed weight per fruit, marketable, unmarketable and total yield(t/ha), fruit dry weight(g), pericarp thickness, fruit length and fruit diameter. As a result, the earliest variety to attain days to 50% flowering was Gojeb Local at Kechema site followed by Mareko Fana at both locations, The variety to attain shortest days to first harvest was recorded from variety Gojeb Local, while the highest number of fruits per plant was from Weldele at Kechema site. On the other hand the highest primary, secondary and tertiary branches were recorded from variety Welwdele at Kechema site.Similarly the thickest fruit size was attained from Mareko Fana at Kechema site, where as,the widest fruit diameter was recorded from Mareko Fana Bako Local, Dube Medium and Dube Short at Kechema site respectively. The highest marketable yield(t/ha) of hot peppers was recorded from Varieties Weldele, Mareko Fana, Dube Medium and Dube Short at JUCAVM and Kechema, respectively, while the highest total yield (t/ha) was recorded from Weldele and Mareko Fana at both locations. The high yielding capacities were attributed to their early flowering and maturity, days to first harvest, high marketable and total yield, dry weight content of the varieties as well as their reaction to disease. Since, the present study was done only for one season at two locations; it would be advisable to repeat the experiment at different locations using different entries of hot pepper in order to arrive at a sound conclusion.

1. INTRODUCTION

Capsicum has been known since the beginning of civilization in the Western Hemisphere. It has been a part of the human diet since about 7500 BC (Mac Neish, 1964). Hot pepper is produced in all the continents except Antarctica, and historically associated with the voyage of Columbus (Heiser, 1976). Columbus is given credit for introducing hot pepper to Europe, and subsequently to Africa and Asia. On his first voyage, he encountered a plant whose fruit mimicked the pungency of the black pepper; *Piper nigrum* L. Columbus called it red pepper because the pods were red. The plant was not the black pepper, but an unknown plant that was later classified as *Capsicum*. The crop spread rapidly across Europe into India, China, and Japan. The new spice, unlike most of the solanums from the Western Hemisphere, was incorporated into the cuisines instantaneously. Probably for the first time, pepper was no longer a luxury spice only the rich could afford. Since its discovery by Columbus, The crop has been incorporated into most of the world's cuisines. It has been commercially grown in the United States, when Spanish colonists planted seeds and grew Chile using irrigation from the Rio Chama in northern New Mexico (DeWitt and Gerlach, 1990).

The genus *Capsicum* is a member of the Solanaceae family that includes tomato, potato, tobacco, and petunia. *Capsicum* was domesticated at least five times by prehistoric peoples in different parts of South and Middle America. The genus *Capsicum* consists of approximately 22 wild species and five domesticated species. The five domesticated species include, *C. annum* L.*, C.frutescens* L.*, C. Chinenses., C. baccatum* L.*, and C.pubescens* R. (Bosland and Votava, 2000). On the other hand*, capsicum* species can be divided in to several groups based on fruit/pod characteristics ranging in pungency, colour, shape, intended use, flavor, and size Despite their vast trait differences most cultivars of peppers commercially cultivated in the world belongs to the species C. *annum* L. (Smith *et al*., 1987; Bosland, 1992).

The exact time of introduction of pepper, which were originated from Latin America, to Africa in general and Ethiopia in particular is not certainly known. But, its history in the country is perhaps the most ancient than the history of any other vegetable product (EEPA, 2003). Moreover, hot pepper has been cultivated in Ethiopia for long period of time. Currently, it is produced in many parts of the country because, for most Ethiopians food is tasteless without hot pepper. That is, it is the main parts of the daily diet of most Ethiopian societies. The fine powdered pungent product is an indispensable flavoring and coloring ingredient in the common traditional sauce "*Wot*", whereas the green pod is consumed as a vegetable with other food items. The average daily consumption of hot pepper by Ethiopian adult is estimated 15g, which is higher than tomatoes and most other vegetables (MARC, 2004).

In Ethiopia, pepper grows under warm and humid weather conditions and the best fruit is obtained in a temperature 21-27^{0}C during the daytime and 15-20^{0}C at night (IAR, 1996). It is extensively grown in most parts of the country, with the major production areas concentrated at altitude of 1100 to 1800 m.a.s.l. (MoARD, 2009).

Hot pepper is one of the major vegetable crops produced in Ethiopia and the country is one of a few developing countries that have been producing paprika and *capsicum* oleoresins for export market. Because of its wide use in Ethiopian diet, the hot pepper is an important traditional crop mainly valued for its pungency and color. The crop is also one of the important spices that serve as the source of income particularly for smallholder producers in many parts of rural Ethiopia. According to the EEPA (2003), in the major pepper producing regions in the country, that is, Amhara, Southern Nations and Nationality People's Regional State (SNNP) and Oromia, pepper generated an income of 122.80 million Birr for farmers in 2000/01. This value jumped to 509.44 million Birr for smallholder farmers in 2004/05. This indicates that hot pepper serves as one of the important sources of income to smallholder farmers and as exchange earning commodity in the country (Beyene and David, 2007).

In spite of its importance, the hot pepper production system for green and dry pod has stayed as low input and low output with a national average yield of 7.6 t/ha for green pod whereas it was 1.6 t/ha for the dry pod respectively (CSA, 2006). The decline of hot pepper production is also attributed to poor varieties, poor cultural practices, the prevalence of fungal (blights) and bacterial as well as viral diseases (Fekadu and Dandena, 2006).

Even though hot pepper is a high value commodity, which has the potential for improving the income and the livelihood of thousands of smallholder farmers in Ethiopia and diversifying and increasing Ethiopia's agricultural export exchange earnings, the crop is confronted with various production and marketing related problems.

Now a days, it is widely recognized that quality product and access to market is a key element in providing a route out of poverty for small scale producers in developing countries including Ethiopia. In Jimma area, hot pepper is a major spice and vegetable crop produced by the majority of farmers in more than nine potential woredas. There is therefore a strong need to help small producers to achieve sustainable production and fair access to pepper markets in order to increase their income and secure their livelihood by providing adaptable and high yielding varieties.

The present situation indicates that in Jimma area there are limited *Capsicum* species and varieties including both improved and the local ones. As a result, varietal information for the improvement of the crop for high fruit yield and quality in the existing agro-ecology is insufficient. There has also been no research on evaluation of hot pepper which enables the growers to select the best performing varieties in the study area. Evaluation of selected varieties was therefore one of the considerations to ease the existing problems of obtaining the desired varieties for which the output of this study was likely to assist and sensitize hot pepper growers and processors. Better adaptable and well performing variety (varieties) with improved cultural practices could be a possibility to boost quality and marketable production of the crop in the study area.

Furthermore, the information generated from the evaluation of selected varieties of hot peppers at JUCAVM and Kechema experimental sites; could serve as guidance to the producers to select varieties that could be best adaptable to the agro-ecology of Jimma area for better production of the crop. Therefore, this study was executed based on the following objectives:

- To investigate the performance of different varieties of hot pepper for growth, dry pod yield and quality under Jimma condition.

- To find out the interaction effects between variety and growing environment.

2. LITERATURE REVIEW

2.1 Origin and Distribution

The origin of *Capsicum* species is extended from Mexico in the North to Bolivia in the South of Latin America, where it has been part of human diet since about 7500BC (Purseglove *et al*., 1981). Spanish and Portuguese explorers spread pepper around the world. Pepper was introduced to Spain in 1493, England in 1548 and Central Europe in 1585. Then, from Europe it spread to Asia. Currently the crop is produced in various countries around the world including India, China, Pakistan, Indonesia, Sri Lanka, Thailand and Japan in Asia and Nigeria, Uganda and Ethiopia in Africa. India and Indonesia have been the largest producers. Currently China is the main producer and exporter in the world.

2.2 Taxonomy and Morphology

Hot pepper (*Capsicum* species) belongs to the Family Solanaceae, Genus *Capsicum,* and species *frutescence* L., group of vegetables. Cultivated peppers are all members of the world *capsicum* species. There are an estimated 1,600 different varieties of pepper throughout the world with five main domesticated species that includes *C. annum* L., *C. frutescens* L. C. *Chinenses.,* C. *baccatum* L*., and C. pubescens* R. (Bosland *et al*., 2000). *Capsicum* peppers are commercially classified by the concentration of *capsaicin* ($C_{18}H_{27}NO_3$) which determines a variety's "hotness", *Capsicum* species are diploid, most having 24 chromosome number (2n=24). But recent studies indicated the chromosome number for non-pungent species is n=13. They vary in size, shape, color, flavor and degree of hotness, from mild to very hot (Tong and Bosland, 2003).

According to Salter (1985), their production and consumption have steadily increased worldwide during the 20th century due to their roles as both vegetable and spices. Just like their Solanaceous cousins, tomato, and potatoes, peppers have rapidly become important components of diverse cuisine around the world. This is reflected in the large acreages devoted to their production in such countries as India, Mexico, China, Korea, USA and Africa. In addition, interest in both sweet and pungent types of peppers is growing in many countries not traditionally associated with spicy cuisine; protected culture has developed in northern latitude countries such as Holland and Canada and also in Mediterranean countries such as Spain, and Israel, to supply the increased demand (Wien, 1997).

Capsicum species have a solitary (single) flower that starts at the axils of the first branching node with subsequent flowers forming at each additional node. Flower differentiation is not affected by day length, but the most important factor determining differentiation is air temperature, especially at night. The capsicum flower is complete, bisexual, hypogenous and usually pentamerous (Bosland and Votava, 2000). Depending on the environmental conditions and variety, the period of receptivity of the stigma is 5-8 days, from several days before anthesis to fewer days afterwards, with maximum fertility on the day of anthesis (Aleemullah *et al*., 2000).

The most actively growing organ of a pepper plant after flowering is the fruit. The fruit is ordinarily seeded, but parthenocarpic forms exist. The seed set affects development and subsequent growth of the fruit. On average there is a direct linear relationship between the number of seeds per fruit and final fruit size, until saturation at perhaps over 200 seeds per fruit (Marcel *et al*., 1997). Typically cultivated fruit reaches the mature green stage in 35-50 days after the flower is pollinated. The fruits are characterized as non-climacteric in ripening (Bosland and Votava, 2000).

2.3 Cultivation and Importance

Hot peppers like most other plants, prefer well drained, moisture holding loam soil (sandy loam) containing some organic matter (Lemma and Edward., 1994). A pH of 6.5-7.5 is suitable and the land should be level to 0.01- 0.03 % slope to allow adequate drainage and prevent root diseases. Adequate water supply is essential. Water stress can cause abscission of fruit and flowers, especially when it occurs during flowering (Matta and Cotter, 1994) and reduces yield through reduced pollination. The extreme case can result in increased risk of diseases. Poorer soil types and water stress are believed to produce lower yields (Haigh *et al.*, 1996).

Hot pepper (*Capsicum* species) is a vegetable crop at its green stage. It is a new world crop that belongs to the *Solanaceae* family (Poulos, 1993). Even though no documented information, it was supposed to be introduced to Ethiopia by the Portuguese in the 17th century (Haile and Zewde, 1989). The demand for specific hot pepper varieties is largely driven by consumer need and interest. The potential areas in the country for capsicum production is estimated to be about 59,991 hectares of land with the total production of 72,466 tone for dry pod and 4783 ha of land with production of 44,273 tones for fresh pod (CSA, 2006).

Much of the recent attention focused on hot pepper can be attributed to their unique pungency that has made them an important spice in the cuisine of various countries. The proliferation of ethnic restaurants and food products from such as Mexico, India and Thailand has positively influenced the demand for peppers throughout the world. Both sweet and hot peppers are processed into many types of sauces, pickles, relishes and canned products.

According to Bosland and Votava (2000), sweet pepper and hot pepper, like tomato and eggplant are rich in Vitamins A and C and a good source of B_2, potassium, phosphorus and calcium (Anonymous, 1998). It has been found that as hot peppers mature, the Pro-vitamin A (B Carotene) and ascorbic acid increase. This has led to extensive production of hot peppers in some countries for export markets. A substantial percentage of pepper acreage in the largest producing countries is dedicated to chili powder. However, the higher prices received by farmers for fresh products have helped sustain the vegetative pepper industry, despite rising production costs competition and increased demand. This increasing demand for pepper to feed the growing human population and supply the ever-expanding pepper industries at national and international level has created a need for the expansion of pepper cultivation in to areas where it has not ever been extensively grown (Beyene and David, 2007).

Hot pepper pungency is a desirable attribute in many foods. Pungency is produced by the *capsaicinoids*, alkaloid compounds ($C_{18}H_{27}NO_3$) that are found only in the plant genus, *Capsicum*. The capsaicinoids are produced in glands on the placenta of the fruit. While seeds are not the source of pungency, they occasionally absorb capsaicin because of their proximity to the placenta. No other plant part produces capsaicinoids (Hoffman *et al*., 1983).

Hot pepper pungency is expressed in Scoville Heat Units (Scoville, 1912). The Scoville Organoleptic Test was the first reliable measurement of the pungency of hot peppers. This test used a panel of limited human representatives, who tasted a *Capsicum* sample and then recorded the heat level. A sample was diluted until pungency could no longer be detected. The most common instrumental method to analyze pungency is high-performance liquid chromatography (HPLC). It provides accurate and efficient analysis of content and type of capsaicinoids present in a capsicum samples. High-performance liquid chromatography analysis has become the standard method for routine analysis by the processing industry. The method is rapid and can handle a large number of samples (Woodbury, 1980).

The *Capsicum* species pungency level has genetic and environmental components. The *capsaicinoid* content is affected by the genetic make-up of the cultivar, weather conditions, growing conditions, and fruit age. Plant breeders can selectively develop cultivars with varying degrees of pungency. Also, growers can somewhat control pungency by the amount of stress to which they subject their plants. Pungency is increased with increased environmental stress. More specifically, any stress to the hot pepper plant will increase the amount of *capsaicinoid* level in the pods. A few hot days can increase the *capsaicinoid* content significantly. In New Mexico, it has been observed that even after furrow irrigation, the heat level will increase in the pods. The plant has sensed the flooding of its root zone as a stress, and has increased the capsaicinoid level in its pods. If the same cultivar was grown in both a hot semi-arid region and a cool coastal region, the fruit harvested from the hot semi-arid region would be higher in capsaicinoids than that of the fruits harvested in the cool coastal climate (Lindsay and Bosland, 1995).

Capsicum fruits are consumed as fresh, dried or processed, as table vegetables and as spices or condiments (Geleta, 1998), because, it increases the acceptance of the insipid basic nutrient foods. The nutritional value of hot pepper merits special attention, because it is a rich source of vitamin A, C and E. Both hot and sweet peppers contain more vitamin C than any other vegetable crops (Poulos, 1993). Oleoresins of paprika and capsicum are the two important extracts of pepper (Bosland and Votava, 2000).

Medicinal use of *Capsicum* has a long history, dating back to the Mayas who used them to treat asthma, coughs, and sore throats. A survey of the Mayan pharmacopoeia revealed that tissue of *capsicum* species is included in a number of herbal remedies for a variety of ailments of probable microbial origin (I-San Lin, 1994). According to Bosland and Votava (2000), pepper is the most recommended tropical medication for arthritis. The pharmaceutical industry uses capsaicin as a counter-irritant balm (cream), for external application of sore muscles (Thakur, 1993). Creams containing capsaicin have reduced pain associated with post-operative pain for mastectomy patients and for amputees suffering from phantom limb pain. Prolonged use of the cream has also been found to help reduce the itching of dialysis patients, the pain from shingles and cluster headaches.

It is not only their nutritional quality and medicinal value that makes peppers an important food crops, but peppers also stimulate the flow of saliva and gastric juices that serve in digestion (Alicon, 1984). It has been said that peppers raise body temperature, relieve cramp, stimulate digestion, improve the complexion, reverse inebriation, cure a hangover, soothe gout and increase passion. On the other hand among its many modern innovative uses it has been tried to use as a barnacle repellent. For example, anti-mugger aerosols with chilies pungency as the active ingredient have replaced mace and tear gas in more than a thousand police departments in the United States. The spray will cause attackers to gasp and twitch helplessly for 20 minutes (Bosland and Votava, 2000).

2.4 Factors Affecting Growth, Yield and Quality of Hot pepper

2.4.1 Planting methods

Capsicum in the field is established either by direct seeding or transplanting depending up on the environmental condition of an area. Both types of planting have their own distinctive advantage or disadvantage over the other (Catter, 1994). According to research results from different parts of Ethiopia, using a standard Bako Local variety, direct sown plots were seen more vigorous than transplanted ones, but the stand percent of direct sown plots were seriously affected by erosion (Sam-Aggrey and Bereke Tsehai, 1985). According to the authors, direct sown plots were affected by lodging due to bearing of more fruits than transplanted ones. In spite of the low stand percent, direct sowing was reported to be by far better than transplanting. Direct sown plots had plants superior in earliness in flowering and fruit set, marketable and total yields.

Similarly, direct sown plants were reported to have a strong tap root than transplants, which form extensive lateral roots because of the early shock after being uplifted from bed. Considering all these factors, therefore, it was concluded that direct sowing of hot pepper should be better than transplanting. In same way, in Yugoslavia, the production of sweet pepper by direct sowing resulted in higher yield and improved quality of pods than transplanting and this was accounted for its higher plant density per unit area (Markovic *et al*., 1989).

Transplanting is used for more precise control of plant population and spacing, thinning, cost avoided, and with efficient use of seed (0.8 to 0.9 kg seeds/ha) than direct planting (6.25 kg seeds/ha) (Salter, 1985: Klassen 1993). Transplanting also affords late planting opportunities for seedling raised in green houses, least amount of water during seedling establishment

(Bosland and Votava, 2000). In some cases, transplanted plants tend to be shorter and have more nodes and have lower total root growth than direct seeded pepper plants.

Research results in USA showed that transplant began flowering at least 16 days earlier and out yielded plants established via direct sowing when grown under condition of environmental stress. But similar investigations indicated that, yields were similar or improved with direct sown rather than transplanted crop (Schultheis, 1988). Leskovar and Cantliffe (1993), on the other hand, reported that transplants exhibited significantly higher and earlier yields than direct sown hot pepper plants. In transplanting, the seedlings from the nursery which were prepared on the raised, sunken or flat seedbed depending on climatic conditions are planted on the actual field.

For the transplanting method in Ethiopian condition, the recommended size of a seedbed is one meter by five or ten meters (Nasto *et al*., 2009). Pepper seed is usually germinated on beds, and a shed using a grass should be erected over the seedlings to protect them from heavy rains and excessive sunlight. If there is no irrigation, transplanting should be done during the beginning of the rainy season. Seedling of 20-25cm height or 45-60 days old should be spaced at 30 cm apart within rows and 70 cm apart between rows. The seedlings should be hardened off by reducing water and exposing them to sun one week before planting (EARO, 2004). While for direct sowing in a row spaced 70 cm apart and 30 cm distance with in a row, six seeds per hole was used (Matta and Cotter, 1994).

In general, transplanting could be applicable in areas receiving long, predictable and ample rainfall. But in areas with erratic rain and short rainy season, the use of direct sowing method is important (Sam-Aggrey and Bereke-Tsehai, 1985), even though, direct sowing is with its own limitations, like that of washing away of seeds, plant lodging and requirement for frequent weeding.

2.4.2 Water requirement of hot pepper

Hot pepper is usually rain fed but can also be grown under irrigation. However, water logging for even a short period of time may cause the plant to shed its leaves and high humidity may encourage the growth of fungal diseases (Bosland *et al.,* 1994). Thus, adequate water supply is essential.

Hot Pepper is also among the most susceptible horticultural plants to drought stress because of the wide range of transpiring leaf surface and high stomatal conductance (Alvino *et al.*, 1994), and having a shallow root system (Dimitrov and Ovtcharrova, 1995). For high yields, an adequate water supply and relatively moist soils are required during the entire growing season. A significant yield reduction was reported by limiting the amount of water supplied during different growing periods such as vegetative, flowering or fruit settings (Doorenbos and Kassam, 1988). Low water availability prior to flowering of pepper reduced the number of flowers and retarded the occurrence of maximum flowering.

The water deficit during the period between flowering and fruit development reduced final fruit production (Jaimez and Edward, 1994; Della Costa and Gianquinto, 2002) reported that continuous water stress significantly reduced total fresh weight of fruit, and the highest marketable yield was found at irrigation of 120% and the lowest at 40% evapo-transpiration (ET). This indicates that total pepper yield was less at lower levels of irrigation (Antony and Singandhupe, 2004). They conducted a hot pepper study applying water through alternate drip irrigation on partial roots (ADIP), fixed drip irrigation on partial roots (FDIP) and even drip irrigation on whole roots (EDIP) and concluded that ADIP maintained high yield with up to 40% reduction in irrigation compared to even drip irrigation on partial root (EDIP) and FDIP, and moreover, best water use efficiency occurred in an alternate drip irrigation on partial root zone (ADIP).

Throughout the world, since the available water for agriculture is generally limited, the knowledge of the relationship between yield and quality of the product and irrigation regimes is an important factor to maximize the benefit of the available water supply. Effective irrigation is essential to obtain the best yields of fruit of the right size. The soil must be kept moist to a minimum depth of 45 cm. During the first two weeks after transplanting, the plants should be irrigated twice or three times per week for the transplants to become established, thereafter, once or twice per week depending on climatic conditions and soil type is advisable (Pellitero *et al.*, 1999).

2.4.3 Fertilizer requirement

The amount of fertilizer to be applied depends on soil fertility, fertilizer recovery rate, and organic matter, soil mineralization of nitrogen(N), and soil leaching of N (Berke *et al.,* 2005). Peppers require adequate amount of major and minor nutrients. However, they appear to be less responsive to fertilizer, compared with onion, lettuce and Cole crops (Cotter, 1986). Study by Hedge (1997) showed that nutrient uptake and dry matter production (fruit yield) of hot pepper are closely related.

The nutrients normally used on peppers are nitrogen and phosphorus. The first nitrogen application and all the phosphorus can be broadcasted before leveling the field. Alternatively, phosphorous can be banded at 8-10 cm below the seed. This is the most efficient method of applying phosphorus. In a nutrient practice in semi arid areas of Senegal, 10 t/ha organic manure, 140 kg/ha N, 100 kg/ha P_2O_2, and 200 kg/ha K_2O is applied on a light soil (Bosland and Votava, 2000).

It is believed that phosphorus results in a better yield and more red colored fruit (Matta and Cotter, 1994). During growth, further nitrogen may be applied to achieve more yields. A side dressing of 22-34 kg/ha of nitrogen is applied when the first flower buds appear and when the first fruits are set (Bosland *et al*., 1994). Too much nitrogen on the other hand can over stimulate growth, resulting in large plants with few early fruits, or delaying maturity and increasing risk of serious plant or pod rots (Bosland and Votava, 2000).

Fertilizer requirements vary with soil type and previous crop history. And thus a balanced nutrient level is required for maximum production. In Ethiopia, the recommended fertilizer rate for the hot pepper is, 200 kg/ha DAP and 100 kg/ha for UREA (EARO, 2004).

2.4.4 Farmyard manure

Animal manures, particularly cattle dung, were the main source of nutrients for the maintenance of soil fertility in settled agriculture until the advent of mineral fertilizers (Ofori and Santana, 1990). Farmyard manures are responsible to nutrient availability for crop in demand, improve soil physical properties (aggregation) and hence improve water retention capacity, infiltration rate and biological activity of soil (Aliyu, 2000.). The advantage of farmyard manure application, however, greatly depends, among others, on proper application methods, which increase the value, reduce cost, and effectiveness (Teklu *et al*., 2004).

2.4.5 Integrated use of farm yard manure and inorganic fertilizer

An integrated approach for the maintenance of soil productivity, with the complementary use of both mineral and organic fertilizers, offers a good opportunity to the small farmer to maintain yields at reasonable and sustainable levels (Ofori and Santana, 1990). Various research reports showed that as it improves quantity and quality of potato (Teklu *et al*., 2004). Experiment conducted in Kenya also indicated that supplementing the inorganic fertilizers with well decomposed farmyard manure substantially increased both to improve soil fertility and potato tuber yield in a small holder farms (Muriithi and Irungu, 2004). The authors also assessed that considering cost of inorganic fertilizer and its negative effects on the environment, reduced usage at half the recommended rate combined with half rates of farmyard manure to be a feasible to the farmers, soil and environment.

2.4.6 Diseases incidence

The main diseases that directly cause the low yield on pepper are virus complex like Pepper Mottle Virus, Fungal diseases including; damping off (*Rhizoctonia solani, Pythium* spp., and *Fusarium* spp), powdery mildew, blight (*Phytophthora capsici*) and fruit rot (*Vermicularia capsici*), Bacterial Soft Rot **(***Erwinia carotovora* pv), Rhizoctonia Root Rot (*Rhizoctonia solani*), bacterial wilt (*Pseudomonas solanacearum*), anthracnose or Ripe Rot (*Collectotrichum capsici*) (MoRD, 2009).

The diseases causes, rotting of the roots and the underground portion of the stem and in severe conditions causes death, some of them cause small, yellow, slightly raised spots appear on young as well as on older leaves, some attacks the crop at seedling stage, as a result followed by yield loss. Therefore, the control measures includes, the use of cultural practices, resistant varieties, rotation of crops, in the severe case chemical action is relevant (EARO, 2004).

2.4.7 Variety

Diverse hot pepper (*Capsicum* species) genotypes have been widely grown in tropics and typical tropical climate within Ethiopia over centuries. More than 100,000 tones (annual average) of dry fruit of hot pepper are produced in the country and used for export for worldwide market but substantial amount are consumed locally as spice which exceeds the volume of all other spices put together in the country. Nowadays there is serious shortage of dry fruits both for export and local markets partly due to very low productivity (0.4 t dry fruit yield/ha) of the crop (Lemma *et al.,* 2008).

Though hot pepper has been cultivated for centuries in typical tropical climate within Ethiopia, the yield has remained very low due to limited improvement work on the crop. However, in the past three decades, diverse genotypes (more than 300) of the crop have been introduced from different regions of the world and local collections have also been made in the country. The genetic improvement of hot pepper is also lacking in the country due to non availability of requisite genetic information. It is well recognized that the knowledge and understanding of the genetic basis of economic traits is important to enhance the progress in developing new varieties of the crop through breeding (Usman *et al*., 1991).

The varietal analysis techniques have been found to be the useful tools to obtain precise information about the types of gene actions involved in the expression of various traits and to predict the performance of the progenies in the latter segregating generations. Each variety has its own significant effect on yield and yield components, and each variety has its own traits that are part and parcel as quality parameters of the crop (shape, size, color, taste and pungency). The most important traits among others include, number of branches per plant (count), plant height, number of fruits per plant, days to maturity (count from days of transplanting), dry fruit yield per plant, fruit length and single fruit weight (Lemma *et al.,* 2008).

Even though about a dozen hot pepper cultivar was released, in Ethiopian pepper research history, two cultivars, namely Mareko fana and Bako local, released in 1976, are being extensively produced in the commercial farms and by the peasant sector (Engels *et al.,* 1991; Alemu and Ermias, 2000).

2.5. Production Status

In Ethiopia the total area under hot pepper production for green pod was to be about 54,376, hectares with the total production of about 770,349. However, the area of coverage in the country increased from 54,376 to 81,544 hectares through 2003/04-2005/06 production years. In recent years the total production has declined due to various reasons, but there is still enormous potential for its production in the country (MARC, 2005).

In Ethiopia, the crop is cultivated at diverse ecological zones from sea level to 2000 m.a.s.l under rain fed and irrigated conditions. The crop is one of the most widely grown and plays major role in Ethiopian daily dishes as it has various home and industrial uses as well as good export potential. Whereas sweet pepper and chili are grown in lower altitudes relatively in warmer areas than for hot pepper and is mainly grown in state farms for export .Birds eye chili, which is the most pungent of all the peppers, is not in great demand, though few plants are commonly found around the homesteads in high rain fall warmer areas of the country (MARC, 2003).

The dry pod yield estimate in small farmer field was about 4q/ha, in the state farm it ranged from 3 q/ha of dry pod yield and 150 q/ha of green pepper but the dry pod yield in experimental plot ranged between 25-30 q/ha. This indicates that hot pepper and other vegetable crops need intensive care and management for high return per unit area.

Yield is dependent on varieties and varieties themselves are considerably depending on a number of factors. In Ethiopia hot pepper production for dry pod has been low with a national average yield of 0.4 t dry fruit yield/ha (Fekadu and Dandena, 2006). This variation in yield is brought about by lack of adaptable varieties with the existing agro-ecology and water during dry seasons which can lead to flower abortion and resulted in low productivity.

Much effort has been made and still continued to solve such production constraints nationally and internationally. As to the national efforts, there are a number of strong vegetable research programs across agricultural research centers throughout the country. In collaboration with regional research centers, and universities, the centers have generated a number of outputs including improved varieties, appropriate agronomic practices and crop protection measures for the vegetable production sector that could be grown in the country both under rain fed and irrigated conditions (Fekadu *et al.*, 2008).

2.6. Varietal Studies and Achievements on Hot pepper

Globally due to its economic importance, especially in Asian countries such as Thailand, China, and the Philippines, the Asian Vegetable Research Development Center (AVRDC) had begun the varietal evaluations to develop more productive and adaptive cultivars for the region. Accordingly, the AVRDC has chosen hot pepper as one of its principal crops. Subsequently, with collaboration from the International Board for plant Genetic Resources (IBPGR), at the very beginning was able to have a collection comprising 5,177 accessions from 81 countries/territories (Yamamoto and Nawata, 2005). The main emphasis of pepper work is centered on collection, multiplication, conservation, characterization, evaluation, documentation, and distribution in comparison with the local varieties which are specific to agro- ecological sites throughout Asia, with the help of evaluation trials, the activity which has not yet been widely and consistently strengthened in our case (AVRDC, 1993).

In Ethiopia Capsicums have been grown for a long time by local farmers and considered as an indigenous vegetable crop and due to a long period of cultivation in different part of the country a great deal of natural hybridization has occurred among different capsicum species. As a result many local genotypes have evolved with various plant and fruit characters as well as disease and pest reactions. Research on *capsicum* started with minor observation and mass selection from local materials in different experimental stations of Awasa and Bako (MARC, 20003).

However, later strong research activities on varietal screening and cultural practices were started at Bako Agricultural Research Center. Major activities like varietal screening against diseases, adaptation studies and plant selections have been attempted at Nazret and Jimma Research Centers and at different trial cites in Gambella and farmers' fields in Southern Showa (Mareko, Tedele, Enseno) and Bako area. In the last 30 years, extensive research has been conducted mainly on hot pepper in different research centers and in Ambo plant protection centers and Haramaya University. Some improved cultivars from each type have been developed and some management practices like spacing, sowing date, rate of fertilizer, planting method, seeding rate and disease and pest control measures were recommended (MARC, 2003). Currently different research activities are also in progress at different centers to alleviate some of the main production constraints and develop better productive varieties from local collections and imported materials.

Among the selection work conducted earlier at Bako and Awasa Research Centers two local selections Mareko Fana and Bako Local cultivars were developed by mass selection, since then they are widely grown in different parts of the country. Mareko Fana with larger and pungent pods with highly demanded dark- red color and Bako Local with high pungency content and yield, in which Bako Local was recommended for high rain fall Western part of the country and Bako areas, for Mareko Fana was recommended for Southern and Oromiya region and other areas with similar environmental and soil conditions. These cultivars are highly preferred by the local consumers owing to their pungency level, attractive color content and high powder yield and acceptable color. Particularly cultivar Mareko Fana is the only cultivar being used for a long time by the local factories for the extraction of capsicum oleoresin for the export market (MARC, 2003).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The study was carried out at two locations, Seka Chokorsa (Kechema nursery site) and Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) experimental field.

Seka Chokorsa district is located at about 374 km from Addis Ababa and 23 kms to the south of Jimma town, at $7^0$36'41"N latitude, and $36^0$44'12" E longitude (JICA, 2003). Altitude of the location ranges 1100-1600 m.a.s.l. and annual minimum and maximum rainfall ranges from1400 to 1601 mm respectively, The mean maximum and minimum temperatures are 30^0C 16^0C respectively and the soil type of the site is Vertisols. Vertisols typically form from highly basic rocks such as basalt in climates that are seasonally humid or subject to erratic droughts and floods, or to impeded drainage (Seka Chokorsa Woreda Agriculture and Rural development Office, 2009, Annual Report Unpublished).

On the other hand, Jimma University College of Agriculture and Veterinary Medicine (the second study site) is situated at about 356 km to South west of Addis Ababa. The college is located at about 7^0 42"N latitude and $36^0 5^0$"E longitude and at an altitude of 1710 m.a.s.l. The mean maximum and minimum temperature are 28.9^0C and 11^0C respectively. The annual rainfall recorded is above 1500 mm. The soil is well drained clay loam to silt clay (BOPEDORS, 2000).

3.2 Experimental Materials

The nine hot pepper varieties including the local check, which were collected from different Agricultural Research Centers, were evaluated under two locations, that is, at Seka chokorsa district (Kechema nursery site) and Jimma University College of Agriculture and Veterinary

Medicine experimental field. The nine varieties of hot pepper were obtained from different agricultural research centers and a local check collected from Gojeb. The varieties used were Mareko Fana, Melka Zala, Weldele, Melka Shote, Bako Local, Oda Haro, Dube Medium, Dube Short and Gojeb Local (Appendix Table 7). Seeds were sown in October, 2009 on a seed bed size of 1x10m. The seed bed was covered with a dry grass for 20 days. Then, beds were covered by raised shade to protect the seedling from strong sun shine and heavy rainfall until the plants were ready for transplanting. Watering was done based on climatic conditions with a fine watering can, and was hand weeded and fungicide (Mancozeb was applied at the rate of 3.6 kg/ha), before the fungal devastation as a preventive activity. Other pertinent agronomic and horticultural practices applicable to hot pepper were also followed in the field.

Table 1.Varieties used for the evaluation trials in 2009/10

variety	Year of Release	Maintainer	Adaptation m.a.s.l	Temperature (^{O}C)	Rain Fall	Seed Source
Mareko Fana	1976	MARC	1400-2200	20/29	600-1337	MARC
Melka Zala	2004	MARC	1200-2200	20/29	900-1200	MARC
Weldele	2004	MARC	1000-2200	15/27	900-1300	MARC
Melka Shote	2006	MARC	1000-2200	15/27	900-1300	MARC
Bako Local	1976	BARC	1400-2120	20/29	600-1237	BARC
Oda Haro	2005	BARC	1400-2200	13.3/27.9	830-1559	BARC
Dube Medium	under study	MARC	1000-1200	15/27	600-1237	JARC
Dube Short	under study	MARC	1000-1200	15/27	600-1237	JARC
Gojeb Local	________	Gojeb Area	______	_________	______	LCPE

Source: EARO, 2004.MARC, 2005, MoARD, 2009.

3.3 Experimental Design

The study was conducted at two locations and nine varieties were arranged in split plot in a Randomized Complete Block Design (RCBD) with three replications at each location to layout the treatments (Raghavaro, 1983). The two locations were considered as a main plot while the nine varieties were as a sub-plot. The plot size at each location was 1.5 m x 3.5 m (with a total plot size of 5.25 m^2). Transplanting to the actual field was done when the seedlings attained 20 to 25 cm height and or at 54 days after sown. The Seedlings were spaced 30 cm between plants and70 cm between rows. 200 kg/ha DAP as a side dressing during the transplanting operation and 100 kg/ha for UREA, half of it during the transplanting and half of it 15 days after transplanting was applied (EARO, 2004). The farm yard manure (Compost) was dispersed in to the soil at a rate of 10 t/ha during and after transplanting (FADINAP, 2000). There were five rows per plot and five plants per row with a total of 25 plants per plot.

As to other agronomic practices, irrigation water was applied to the transplants on surface to facilitate plants establishments, and then up to the time of full plant establishments, water was applied using watering can once a day. Then based on the environmental conditions watering was done three times a week afterwards. Hand weeding was done frequently as per the emergence of the weeds. Plant protection was part of the field practices where cultural and chemical control measures were taken and brought about successful results. Cutworms have been occurred during the early seedling establishments on the actual field, where as Fusarium wilt was a problem at vegetative and subsequent plant development stages on few varieties. But put under control by frequent assessments and killing of the cut worms and with the use of Mancozeb (3 kg/ha) fungicides spray in three rounds as a preventive activity (the first at vegetative growth, the second at pod setting stage and the third at green pod stage) and was practiced according to the label (EARO, 2004) to reduce the wilt damage when the plants were at knee height stage after transplanting, at the flowering stage and at green pod yield stage according to the label.

The testing locations represent major hot pepper producing areas of the study area having typical tropical and sub-tropical climate. Hence, the varieties were expected to express their full genetic potentials for the characters under consideration.

3.4 Data Collected

Data were collected from the middle nine plants from central rows excluding the border rows and the rest of all response variables were recorded from the average of those nine selected sample plants per plot at each location, as indicated below.

3.4.1 Growth characters

Plant height (cm): Plant height measurement was made from the soil surface to the top most growth points of above ground plant part. The measurement was taken as the length from nine plants of central rows of each plot at the last harvesting time.

Days to 50% flowering: Is the number of days where 50% of the selected plants started blooming beginning from the days of transplanting.

Number of flowers per plant: The number of flowers of the nine sample plants at 100% flowering stage from each plot were counted.

Days to first harvest: The number of days from transplanting to the date of first harvest was recorded from nine sample plants selected from central rows.

Canopy diameter (cm): The mean values were taken at fruit maturity at both locations by measuring diameter of the plant (North to South and East to West dimension of the above ground part of sample plants).

Number of branches per stem: Numbers of primary, secondary and tertiary branches per stem of randomly selected nine middle row plants at final harvest were counted.

Dry weight content per plant (g): Mean values of the dry weight content (shoots and roots). The samples were dried in an oven at 105^{o}C until constant weight was reached.

3.4.2 Yield and yield related parameters

Number of fruits per plant: Mean number of red ripe fruits of individual plants from central rows for each plot at each harvest was recorded.

Average number of seed per pods: Seeds of randomly picked ten marketable pods from sample plants were counted and recorded.

Seed weight (g): Seed extracted from ten marketable pods were weighed using sensitive balance and mean values were calculated.

Marketable yield (t/ha): The marketable yield of nine sample plants were determined at each harvesting by sorting dried fruits according to color, shape, shininess, firmness and size of the fruits. After drying, the dried marketable fruits were separated, the weight of the respective categories were recorded and converted to t/ha.

Unmarketable yield (t/ha): Is the yield which was obtained by sorting the diseased, discolored, shrunken shape and small sized, totally unwanted pods by consumers from marketable dried pods were recorded at each harvest and converted to t/ha .

Total dry fruit yield (t/ha): Weight of total (marketable and unmarketable) fruits harvested at each successive harvesting from the sample plants was recorded and summed up to estimate yield per hectare.

3.4.3 Quality parameters

Fruit pericarp thickness (mm): Pericarp of ten marketable fruits from each plots were measured using venire caliper and mean values were recorded.

Fruit dry weight content (g): of five plants from each plots was taken. The samples were dried in an oven at 105^{o}C until constant weight was reached.

Fruit length (cm): Length of ten marketable fruits from each plot for each varieties were measured at red and dried stage using venire caliper and mean values were taken.

Fruit diameter (cm): Fruit wall was measured from ten marketable fruits of sample plants from each plot at red ripe and dried stage using venire caliper and mean values were recorded.

3.4.4 Disease reaction

Pest and Disease Incidence (%): The number of infected plants was considered and percentage of plants infected with bacterial wilt incidence estimated as suggested by Agrios (2005):

$$\text{Disease Incidence (\%)} = \frac{\text{Number of infected plants per plot} * 100}{\text{Total number of plants per variety}}$$

3.5 Data Analysis

For each measured response variables analysis of variance (ANOVA) mean separation procedure was carried out. The classical fixed effect analysis of variance model that includes the main effects of locations, varieties together with interaction effects of locations and varieties were used. The ANOVA model used for the analysis was: $\boldsymbol{Y_{ij}=\mu+V_i+L_j+(VL)_{ij}+\varepsilon_{ij}}$ Where, Y_{ij}= the mean value of the response variable of the i^{th} variety at the j^{th} location and the right hand side of the equation gives the grand mean value (μ) and the respective main and interaction effects of varieties and locations. ε_{ij} is a random error term due to those uncontrolled factors.

After fitting ANOVA model for those significant interactions or main effects a mean assumption procedure using LSD mean methods were carried out at required levels of probability. Simple correlation analysis between different characters was also computed to observe associations between characters. In order to assess the associations between those measured response variables a Pearson correlation procedure was carried out. All the statistical analysis was carried out using SAS-9.2 statistical soft ware package.

4. RESULTS AND DISCUSSION

The analysis of variance indicated significant difference between locations and among different tested hot pepper varieties and there was also interaction effect with respect to vegetative growth, yield and quality parameters. Hence, the results are presented and discussed here under.

4.1 Growth Parameters

4.1.1. Plant height (cm)

Significant difference was observed between locations and varieties at ($p<0.001$) and ($p<0.05$) based on the selected parameters, but there was not interaction effect of locations with varieties concerning plant height. Accordingly, the tallest plant height was recorded from variety Weldele (36.50 cm) followed by Melka zala (29.57 cm). The shortest plant height was attained from variety Oda Haro (22.16 cm). Even though, the measured heights differed among varieties (Fig. 1), this result agree with the works of MARC (2005), which reported that varieties Weldele and Melka Zala showed the tallest plant height of 61 and 62 respectively among the evaluated varieties at three locations.

The increase in plant height could mainly be due to better availability of soil nutrients in the growing areas, especially Nitrogen and Phosphorus which have enhancing effect on the vegetative growth of plants by increasing cell division and elongation and the varietal variability to absorb the nutrients from the soil (Vos and Frinking, 1997; El-Tohamy *et al*., 2006). The result of this study confirms the finding of Gonzalez *et al.* (2001) who reported that organic manure and inorganic fertilizer supplied most of the essential nutrients at growth stage resulting in increase of growth variables including plant height.

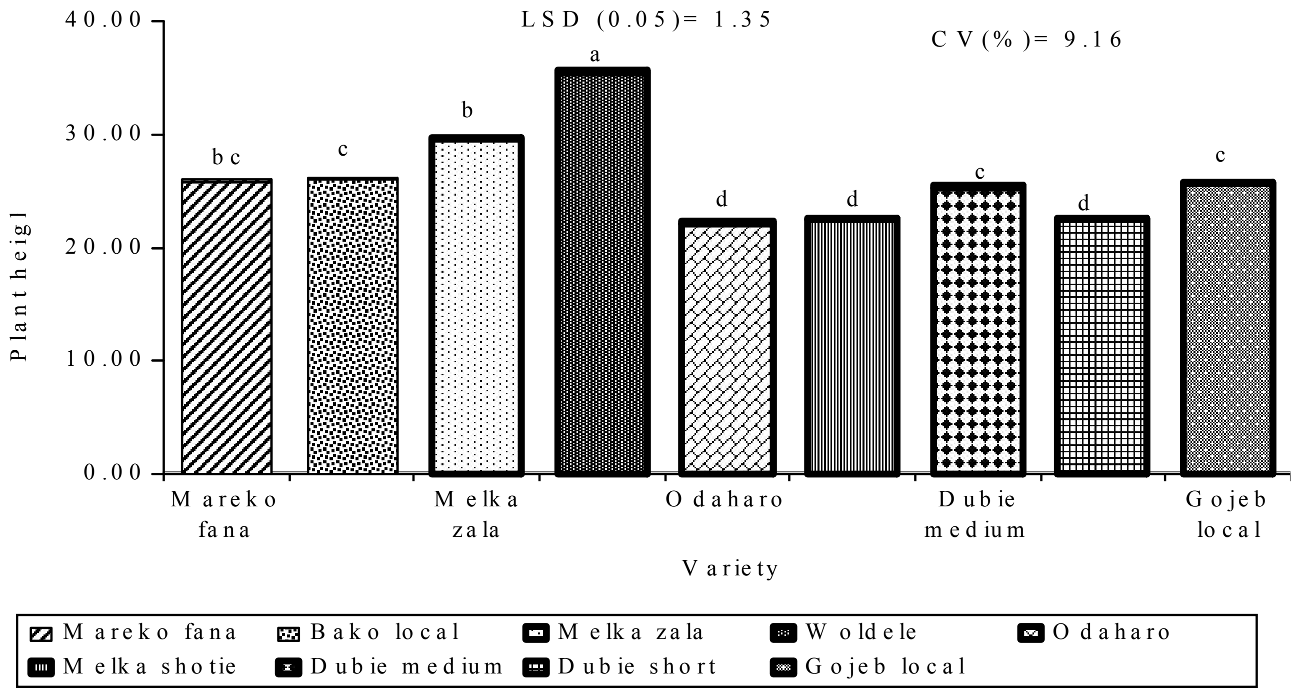

Fig.1. Main effect of plant height on yield and yield components of hot pepper varieties

4.1.2 Days to 50% flowering

The number of days to fifty percent flowering showed very highly significant ($p<0.001$) difference between varieties and there was significant interaction between location and variety (Table 2 and Appendix Table 1). Earliest numbers of days to reach 50% flowering was observed from variety Gojeb Local (46.67 days) at Kechema experimental site, even though it is statistically similar with Mareko Fana at both locations. While the longest days to attain 50% flowering was recorded from Melka Zala (70.67 and 66.00 days) at Jimma and Kechema (Seka) respectively, where Oda Haro and Melka Shote at Jimma and Weldele at Kechema were intermediate.

Earliness or lateness in the days to 50% flowering might have been due to their inherited characters, early acclimatization to the growing area to enhance their growth and developments and/ or due to the transplanting disturbance since it is subjected to loss of feeder roots during uplifting, and consumed their energy to repair damaged organs and thus the process demanded them more time to resume shoot growth. Moreover, the earliness or lateness in days to flowering could also be affected by high temperature of the growing area (that reaches about 32^0C during flowering) that may enhance the flowering nature of the crop.

This result, therefore confirmed the findings of Sam-Aggrey and Bereke-Tsehai (1985) that reported earliness or tardiness in flowering of pepper plants could be affected by the growing environment as well as the planting methods.

4.1.3. Number of flowers per plant

Interaction effect of location by varieties on number of flowers showed very highly significant ($p<0.001$) under this study (Table 2 and Appendix Table 2). Accordingly, the highest number of flowers per plant was recorded from variety Melka Shote (159.67) at Jimma site, whereas, the least number of flowers per plant was also observed from the same variety at Kechema. But, as this indicated, the number of flowers did not commensurate the number of fruits per plant. Weldele and Gojeb Local at Jimma and Weldele again at Kechema were intermediate, and the rest were low.

These variations could be due to the flower inhibitory effect of high temperatures on flowering, lack of optimum soil moisture at the time of flowering of the crop especially at Kechema. Moreover, the primary cause of poor flowering and fruit set as well as marketable yield loss could be due to diseases, wind and heavy rain during flowering in decreasing effective pollination that resulting in loss of potential fruit, frost causes flower and fruit damage and loss of yield. This result is in agreement with the work of Faby (1997), Geleta (1998), Durner *et al.*, (2002), and Sreelanthakumary and Rajamony (2004), who indicated that, the inhibitory effect of high temperature should be considered during the flowering period.

4.1.4 Days to first harvest

The interaction effect of location by varieties indicated very highly significant variation ($p<0.001$) on hot pepper (Table 2) on days to first harvest. Accordingly, the shortest number of days to first harvest was recorded from variety Gojeb local (66 days) at Jimma experimental field. The longest day to attain days to first harvest was recorded from variety Dube Short (149), though it is statistically similar with Oda Haro (147.67), Melka Zala

(147.67), Bako Local (145.67) and Mareko Fana (139) respectively at Kechema nursery site, which is in line with the works of MARC (2005) that reported cultivars like Melka Zala are later than others to mature. The variations in days to first harvest (maturity) could be due to the differences in the growing environment climatic conditions and or due to the genetic make-up of the varieties. For best growth and fruit maturity and quality, it should be grown in an area with a temperature of (21-29^{0}C day) and (15-20^{0}C night) and soil pH of 6.5-7.5.

4.1.5. Canopy diameter (cm)

The analysis of variance showed that there was a significant ($p<0.01$) interaction of variety with location (Table 2 and Appendix Table 1). The result indicated that the widest canopy diameters were obtained from variety Bako Local (22.18), Gojeb Local (21.33) and Weldele (21) and at Seka (Kechema site). Where as all the cultivars were lower at Jimma site and were not better than the check. These variations in canopy diameter between varieties might be due to their inherited traits, the growing environment's soil type, and rainfall and soil pH. This variation on the other hand, may determine the yielding potential of the crop, since, varieties with wider canopy diameter could produce more fruit (pods) than varieties with narrow canopy due to increased number of secondary and tertiary branches which are the locations for fruit bud formation. This is in conformity with the work of Faby (1997) who has reported that plants with wider crown produced higher early season yield than those with small crown. Aliyu *et al*. (2002), used the crown diameter as the main variable to identify the quality of strawberry transplants.

Table 2. Mean values of days to 50% flowering, number of flowers, days to first harvest, and canopy diameter as affected by the interaction of location with variety in 2009/

Variety	Days to 50% flowering		Number of flower per plant		Days to first harvest		Canopy width (cm)	
	Jimma	Kechema	Jimma	Kechema	Jimma	Kechema	Jimma	Kechema
Mareko Fana	51.33[jk]	50.33[jk]	93.67[e]	50.33[jk]	102.67[f]	139.00[ab]	15.33[fgh]	19.00[bcd]
Bako Local	59.33[cd]	58.67[efg]	95.33[df]	54.23[ij]	123.67[cd]	145.67[ab]	15.67[efgh]	22.18[a]
Melka Zala	70.67[a]	66.00[b]	80.33[f]	75.40[de]	118.67[de]	147.67[a]	14.33[hi]	14.67[ghi]
Weldele	56.67[efgh]	60.33[cde]	135.67[b]	126.67[c]	135.00[bc]	103.33[f]	16.33[defgh]	21.00[ab]
Oda Haro	64.00[bc]	60.67[cde]	100.00[d]	58.57[i]	124..7[cd]	147.67[a]	17.33[defgh]	11.93[i]
Melka Shote	63.67[bcd]	63.33[bcd]	159.67[a]	45.86[k]	135.00[bc]	123.33[cd]	16.67[defgh]	17.33[defg]
Dube Medium	53.67[hij]	58.33[efg]	99.78[d]	72.25[g]	104.67[ef]	148.33[a]	18.10[cde]	19.08[bcd]
DubeShort	54.33[ghij]	57.67[efgh]	97.33[bc]	66.05[h]	102.33[f]	149.00[a]	17.33[defg]	16.00[efgh]
Gojeb Local	55.67[fghi]	46.67[k]	125.33[c]	50.67[jk]	66.00[g]	134.00[bc]	18.00[cdef]	21.33[ab]
LSD (0.05)	6.00		1.93		2.24		2.77	
CV (%)	4.59		16.63		13.75		9.48	

Values in each column sharing same letter are not significantly affected at (α = 0.05)

4.1.6. Number of primary, secondary and tertiary branches

The interaction effect of location by variety for the number of primary ($p<0.01$), secondary ($p<0.001$) and tertiary branches ($p<0.01$) indicated significant, very highly significant and significant variations between hot pepper varieties and location respectively (Table3 and Appendix Table 2). The highest number of primary branches were attained from variety Weldele (11), but was not statistically different from Mareko Fana (9.33), Bako Local (9.15), Melka Shote (9.30) at JUCAVM experimental field and Oda Haro (9) at Kechema nursery site. Whereas the least number of primary branches was recorded from Oda Haro (4.27) at Jimma, Bako Local (4.69) followed by Gojeb Local (4.84) at Kechema, respectively.

The highest number of secondary branches was also recorded from variety Weldele (22.33) at Kechema, whereas the least number of secondary branches were observed from Melka Shote and Dube Short (5.33) at Jimma and Kechema respectively (Table 3 and Appendix Table 2).

Tertiary branch, the most important to extend harvest bearing later set fruits since it enables the crop to produce extra fruits was affected by the interaction of location and variety (Table3 and appendix Table 2). Accordingly, the highest number of tertiary branches were attained from variety Gojeb Local (26.99) followed by Mareko Fana (22.44) and Bako Local (22.41) at Kechema nursery site and Dube Short (24.19) at Jimma experimental field respectively. While the least territory branches were attained from Bako Local (7.41) though it is statistically similar with Mareko Fana, Oda Haro and Dube Medium at Jimma experimental field. The overall result regarding the tertiary branches was lower at Jimma.

Generally, the differences observed in branching of pepper plants might have been due to genetic variations existed between varieties and or due to favorable influence of organic and inorganic nutrients present in the soils or the growing environment which goes in line with the findings of (El-Tohamy *et al.,* 2006) that stated the presence of adequate amount of organic nutrients in the soil improves growth of pepper plants. Organic nutrients increase the biomass of pepper plants, as supported by report of Johnson and (Nonnecke,1996), who observed similar effects by application of different levels of organic manure into the hot pepper growing soils.

Table 3. Mean number of primary, secondary and tertiary branches as affected by the interaction of location with variety in 2009/10

Varieties	Primary branch number		Secondary branch number		Tertiary branches number	
	Jimma	Kechema	Jimma	Kechema	Jimma	Kechema
Mareko Fana	9.33^{ab}	6.59^{cde}	8.00^{ghi}	13.02^{bc}	8.59^{fghi}	22.44^{ab}
Bako Local	9.15ab	4.69^{ef}	9.33^{fgh}	11.85^{cde}	7.46^{hi}	22.41^{ab}
Melka Zala	8.67^{bc}	6.50^{cde}	8.00^{ghi}	12.48^{bcd}	8.08^{ghi}	9.45^{cd}
Weldele	10.67^{a}	6.71^{cd}	6.00^{ij}	22.33^{a}	11.99^{efg}	21.28^{bc}
Oda Haro	4.27^{f}	9.00^{ab}	6.00^{ij}	9.51^{fgh}	8.99^{fghi}	22.64^{ab}
Melka Shote	9.30^{ab}	5.67^{def}	5.33^{j}	10.11^{efg}	7.54^{hi}	12.82^{ef}
Dobe Medium	5.67^{def}	5.51^{def}	6.00^{ij}	10.93^{cdef}	8.61^{fghi}	16.30^{de}
Dube Short	8.00^{bc}	5.20^{def}	5.33^{j}	10.62^{def}	24.19^{ab}	9.71^{cd}
Gojeb Local	8.00^{bc}	4.84^{ef}	7.67^{hi}	14.48^{b}	11.08^{fgh}	26.99^{a}
LSD (0.05)	1.93		2.24		4.32	
CV(%)	16.63		13.75		17.59	

Values in each column sharing same letter are not significantly affected at (α = 0.05)

4.1.7. Shoot and root dry weight (gm)

The analysis of variance with interaction effect of location and varieties showed highly significant difference ($p<0.01$) on shoot and significant difference on root ($p<0.05$) dry weight per plant (Table 4 and Appendix Table 5).

Accordingly the highest shoot dry weight was scored from variety Weldele (56.63) while the least was from Gojeb Local (14.71) at Jimma experimental field. The highest root dry weight per plant was obtained from Gojeb local (6.70) at Kechema followed by Weldele at Jimma (5)

Kechema (5.17) respectively. While the least root dry weight was scored from Dube Medium at Jimma experimental field (2.47 and at Kechema (3.08), respectively and Oda Haro (3.13) at Kechema.

The recorded highest dry weight of pepper shoots and roots in this study might be attributed to vigorous and better plant architecture the varieties recorded, that could increase photosynthetic reactions of the crop, thereby increase assimilate partitions towards pods. The increase in pod dry weight in this study conforms with the work of Hedge (1997) who reported that pod dry matter content of peppers was directly related to the amount of nutrient taken from the soil, which was proportional to the nutrients present in the soil or the amount of organic and inorganic fertilizers applied to the soil. Similarly, the work of Guerpinar and Mordogan (2002) had conformity with this study, which discovered that integration of farmyard manures with supplemental dose of inorganic fertilizer could give highest pod dry matter for hot pepper crops.

Table 4. Mean values of shoot and root dry weight as affected by the interaction of location with variety in 2009/10

	Shoot dry weight (g)		Root dry weight (g)	
Variety	Jimma	Kechema	Jimma	Kechema
Mareko Fana	33.89^{bc}	25.97^{efgh}	3.43^{fgh}	3.89^{defg}
Bako Local	30.57^{bcde}	20.79^{ghij}	4.66^{cd}	3.08^{hi}
Melka Zala	30.90^{bcde}	21.90fghi	3.57^{efgh}	4.19^{def}
Weldele	56.63^{a}	32.28^{bcd}	5.00^{ab}	5.17^{ab}
Oda Haro	36.27	19.73^{ij}	4.63^{cd}	3.13^{ghi}
Melka Shote	26.27^{efg}	26.93^{def}	4.50^{cd}	4.25^{de}
Dobe Medium	36.47^{b}	31.77^{bcde}	3.97^{def}	2.47^{h}
Dube Short	36.27^{b}	27.33^{def}	3.69^{efgh}	3.88^{defg}
Gojeb Local	14.71^{j}	28.02^{cde}	4.66^{cd}	6.70^{a}
LSD (0.05)	5.97		1.87	
CV (%)	12.40		11.1	

Values in each column sharing same letter are not significantly affected at ($\alpha = 0.05$)

4.2 Yield Parameters

4.2.1 Number of fruits per plant

Results of analysis of variance indicated a very highly significant interaction ($p<0.001$) among the varieties and location in terms of number of fruits per plant (Table 5 and Appendix Table 3). Variety Weldele had the highest number of fruits (72.3) at Kechema nursery site, while the least number of fruits per plant was recorded from variety Bako Local (24.55) at Kechema nursery site and Dube Short (31) at Jimma experimental field respectively.

The variations in fruit yield might be due to the influence of the growing environment's temperature, associated traits like canopy diameter that could limit the number of branches. Because, as a number of primary, secondary and tertiary branches increased, there could be a possibility of increasing the number of fruit producing buds which are the locations for fruit production. Moreover, the variations in fruit development among varieties at both locations could also be due to the temperature stress of the growing environment and the capability of each varieties to with stand the stress specially on the reproductive development, which is more sensitive to high temperature stress (day and night temperature) than vegetative development. This result is inline with the work of Sato (2005), who reported that, the reduction of fruit set under moderately elevated temperature stress was mostly due to a reduction in pollen release and viability in tomato plant (*Lycopersicum esculentum* Mill.).

On the other hand, number of fruit can be affected by fruit abortion and predation have all been proposed as factors explaining low fruit set in plants. This also is in agreement with Schemske (1980) who reported that, Pollination can be the first factor limiting fruit production.

In general the interaction of location by varieties had relatively better effect on the number of fruits per plant as it has been observed at the two experimental sites. The relative earliness in flowering and maturity could also have enabled the varieties to produce more pods per plant, which contributed for higher productivity of the varieties per unit area.

4.2.2 Number of seeds per fruit

Interaction effect of location by variety showed a very highly significant difference ($p<0.001$) on number of seeds per pod (Table 5 and Appendix Table 3). The highest number of seeds was recorded from Dube Short (160.67) at Kechema; whereas the least number of seeds were recorded from Gojeb Local (46.38) at Jimma experimental field.

This result is in line with Marcelis and Baan Hofman-Eijer (1997), and Lemma (1998), who pointed that seed number per pod is one factor that determine pod size. They observed a linear increase in individual fruit size and weight with seed number. Furthermore, this report is consistent with that of Russo (2003) and Aleemulah *et al*. (2000), who observed positive relationship between seed number and pod size, where fruit weight increased linearly with seed number in sweet pepper. Pepper plants that exhibited high vegetative growth due to effects of treatments have gained high leaf area, increased photosynthetic capacity and assimilate partitioning that resulted large pod size and hence in greater seed number per pod and large pod size.

4.2.3 Seed weight per fruit (g)

A very highly significant($p<0.001$) interaction effect of location and variety was observed on seed weight per fruit (Table 5 and Appendix Table 4).The maximum weight (1.32) was attained from variety Dube Short and the least seed weight was registered from variety Melka Zala (0.42) and Oda Haro (0.51), respectively. This might be attributed to the genetic make-up of varieties and/or the agro ecological factors including, soil type and its nutrient contents, temperature, availability of irrigation or rain water in the growing area based on the study period. Because, pods with higher seed weight can be considered as those receiving higher percentage of assimilate, which also indicate that a good combination of number of seeds and seed weight per pod could improve pod quality through increase of seed weight and pod size. Bosland and Votava (2000), indicated that, in some cultivars of Chili seed can contain up to 60% of the dry weight of the fruit which makes it an important economic part of the crop.

Table 5. Mean values of fruit per plant, number of seeds, and seed weight per pod as affected by the interaction of location with variety in 2009/10

Varieties	Number of fruit per plant		Seed number per fruit		Seed weight per fruit (gm)	
	Jimma	Kechema	Jimma	Kechema	Jimma	Kechema
Mareko Fana	45.18^{def}	57.86^{b}	122.96^{c}	90.14^{fg}	1.03^{bc}	1.12^{b}
Bako Local	43.82^{efg}	24.55^{j}	82.91^{fgh}	79.30^{gh}	1.06^{bc}	0.91^{cde}
Melka Zala	38.35^{gh}	52.55^{c}	117.39^{cde}	91.07^{f}	0.42^{i}	1.14^{b}
Weldele	61.33^{b}	72.33^{a}	77.55^{h}	`104.02^{e}	0.67^{gh}	0.77^{efg}
Oda Haro	52.40c	48.55^{cdef}	114.63^{cde}	116.82^{cd}	0.51^{hi}	0.73^{fg}
Melka Shote	47.01^{cdef}	51.59^{cd}	86.18^{fgh}	86.95^{fgh}	0.79^{efg}	1.05^{bc}
Dobe Medium	43.45^{fg}	51.48^{cde}	110.96^{de}	105.33^{e}	1.01^{bcd}	0.92^{cde}
Dube Short	31.00^{ij}	29.29^{ij}	108.56^{de}	160.67^{a}	0.84^{ef}	1.32^{a}
Gojeb Local	52.55^{c}	47.40^{cdef}	46.38^{i}	141.59^{b}	0.85^{def}	1.08^{bc}
LSD (0.05)	8.9		5.30		0.50	
CV (%)	15.43		0.50		12.70	

Values in each column sharing same letter are not significantly affected at (α =0.05)

4.2.4 Marketable yield (t/ha)

Interaction effect of varieties by locations exhibits a highly significant ($p<0.01$) differences on the marketable yield per ha (Table 6 and Appendix Table 4). The highest marketable yield was obtained from variety Weldele (1.93) at Kechema, while the least from Melka Shote (0.51) at the same location. This result is in conformity with the work of MARC (2005) in which the marketable yield of Weldele and Mareko Fana ranged between 1.5 and 2. The recorded variations of varieties in marketable yield could be due to their differences in genetic make-up and/or agro ecological adaptations compared to the locations in which they had evaluated, which is in line with the findings of Fekadu and Dandena (2006), who reported that the magnitude of genetic variability and heritability are necessary in systematic improvement of hot pepper for fruit yield and related traits.

4.2.5 Unmarketable yield (t/ ha)

Interaction effect of variety by location showed a significant difference ($p<0.05$) on unmarketable yield (Table 6 and Appendix Table 4). The Highest unmarketable yield was obtained from Mareko Fana (0.52) at Jimma, while the least was Gojeb Local (0.043) at Kechema. This unmarketable yield was recorded through subjective judgment based on shrunken shaped fruits, small sized, and discolored fruits that were estimated to be due to the differences in the inherent characters of the varieties, those lacked uniformity when drying, and or due to physiological disorders (bleaching) during the fruit set or due to the climatic conditions of the growing environment during harvesting.

4.2.6 Total yield (t/ ha)

A very highly significant ($p<0.001$) interaction effect was observed on total yield (Table 6 and Appendix Table 5). Accordingly, the highest total dry pod yield (2.18) was recorded from Weldele at Kechema, while the least total dry pod yield was recorded from Melka Shote (0.64) at the same location. Even though this study is a one season trial, the result disagrees with the evaluation trials undertaken at three locations by Melkasa Agricultural Research Center (2005) which indicated that the highest dry pod yield was recorded from variety Melka Zala (1.7) which produced a total dry pod yield of (1.35) in the study area (Jimma). This is much lower than the average fruit yield of the crop (2.53) reported by MARC (2005). This could be due to the climatic conditions (i.e. the temperature, the soil type, the altitude) difference in which the crop was evaluated.

On the other hand, the increase in total pod yield could be due to variation in plant height, as well as formation of more primary, secondary and tertiary branches that increase potential of pod bearing buds and also leaf area that maximizes photosynthetic capacity and assimilate partitioning to the pods. This result is further consolidated by the findings of Sam-Aggrey and Bereke-Tsehai (2005) who reported positive impact of vegetative growth up on yield and yield components of hot pepper. Bosland and Votava (2000) also pointed out that primary and secondary branches were locations of fruit buds and thus foundations of new fruit bud development in bell peppers. Their report is in conformity with the present result, consolidating the role of branches in determining pepper total pod yield.

Table 6. Mean values of marketable, unmarketable and total yield (t/ha) as affected by the interaction of location with variety in 2009/10

Varieties	Marketable yield (t/ha)		Unmarketable yield (t/ha)		Total yield (t/ha)	
	Jimma	Kechema	Jimma	Kechema	Jimma	Kechema
Mareko Fana	1.37^{bcde}	1.69^{ab}	0.52^{a}	0.31^{cd}	1.89^{abc}	2^{ab}
Bako Local	1.051^{cdefg}	0.81^{fgh}	0.18^{fghi}	0.36^{bc}	1.231^{defg}	1.17^{efgh}
Melka Zala	0.99^{defgh}	1.24^{bcdef}	0.36^{bc}	0.10^{ij}	1.35^{efgh}	1.34^{cdef}
Weldele	1.55^{abc}	1.93^{a}	0.47^{ab}	0.25^{def}	2.02^{ab}	2.18^{a}
Oda Haro	0.79^{fgh}	0.83^{fgh}	0.20^{efgh}	0.13^{ghij}	0.99^{fghi}	0.96^{fghi}
Melka Shote	0.67^{gh}	0.51^{h}	0.05^{j}	0.12^{hij}	0.72^{ghi}	0.63^{i}
Dobe Medium	1.25^{bcdef}	1.49^{abcd}	0.44^{ab}	0.23^{cde}	1.69^{abcde}	1.72^{abcd}
Dube Short	1.1^{cdefgh}	1.46^{abcd}	0.36^{bc}	0.16^{ghi}	1.46^{bcde}	1.82^{bcde}
Gojeb Local	0.55^{gh}	0.84^{efgh}	0.10^{ij}	0.04^{j}	0.65^{ghi}	0.88^{fghi}
LSD (0.05)	5.3		1.24		0.92	
CV (%)	12.87		15.69		8.95	

Values in each column sharing same letter are not significantly affected at (α = 0.05)

4.3. Quality Parameters

4.3.1 Fruit length (cm)

A highly significant (p<0.01) interaction was observed between varieties and location in terms of their fruit length (Table 7 and Appendix Table 3). Consequently, the longest fruits were recorded from variety Mareko Fana (15.65), followed by Dube Short (14.67), and Dube Medium (14.04) at Kechema. The shortest length was recorded from Oda Haro (5.06), followed by Weldele (6.33) and Melka Zala (6.78) at Jimma. The over all fruit length was shorter at Jimma. The result agrees with that of MARC (2005) which reported that the long fruit length of (15cm) and the short fruit length with (7cm) at similar variety trial. The variations were most probably being attributed to their inherited traits or the growing environment.

4.3.2 Fruit diameter (cm)

A very highly significant (p<0.001) interaction effect of location by variety was recorded on fruit diameter ((Table 7 and Appendix Table 3). The widest fruit was obtained from variety Mareko Fana (2.77), followed by Dube Short (2.54), Dube Medium (2.52) and Bako Local, at Kechema experimental site, while the least fruit width was observed from Oda Haro (1.14) at Kechema site. The variations in fruit diameter could be due to the difference in varieties inherited characteristics and or due to environmental conditions of the growing areas. This result is in line with MARC (2005) which showed that variety Mareko Fana had a fruit diameter of 2 cm. The pod width difference among varieties could be due to different dry matter partitioning ability of plants and the soil fertility status of the growing locations. Larger and wider hot pepper pods are considered to be the best in quality and have better demand for fresh as well as dry pod use in Ethiopian markets (Beyene and David, 2007). Therefore, subjectively this quality attribute, along with pod length and pericarp thickness could be of better preference to consumers over thinner and shorter pods.

4.3.3 Fruit dry weight (g)

The analysis of variance on interaction effect of location with varieties showed a very highly significant difference ($p<0.001$) on fruit dry weight per plant (Table 7 and Appendix Table 5). The highest fruit dry weight per plant was obtained from Melka Zala (6.75) at Kechema. The increase in pod dry weight in this study is in conformity with the work of Hedge (1997) and Guerpinar and Mordogan (2002) who reported that pod dry matter content of peppers was directly related to the amount of nutrient taken from the soil, which was proportional to the nutrients present in the soil or the amount of organic and inorganic fertilizers applied to the soil.

The least fruit dry weight (2.07) was obtained from variety Gojeb Local, followed by Dube Medium (2.18), Weldele (2.41), Mareko Fana (2.60) and Melka Shote (2.70) at Jimma experimental field. The variations in fruit dry weight among varieties may be due to the genetic make up of the varieties, and or due to the agro-ecological variations in which the varieties were evaluated.

4.3.4 Fruit pericarp thickness (mm)

The analysis of variance indicated a highly significant interaction effect of varieties with location ($p<0.01$) on fruit pericarp thickness (Table 7 and Appendix Table 7). The thickest pericarp (1.32) was observed from Mareko Fana at Kechema experimental site. On the other hand, the thinnest thickness was observed from Melka Zala (0.11) and Weldele (0.13) at Jimma experimental field. These differences might be due to the fact that, the varieties assimilate partitioning capacity that might be resulted in thickest or thinnest fruit pericarp and or due to agro-ecological variations for the two study sites.

This result is in agreement with the work of Winch (2006) who reported that larger onion bulbs were the result of the accumulation of high photosynthetic products and high photo-assimilate partitioning ability of the crop that could be considered as one of the hot peppers' quality attribute among several factors in increasing the amount of powdered dry pod.

Table 7. Mean values of fruit length, fruit diameter, fruit dry weight and fruit periccarp thickness as affected by the interaction of location with variety in 2009/10

Variety	Fruit length (cm)		Fruit diameter (cm)		Fruit dry weight (gm)		Fruit pericarp thickness(mm)	
	Jimma	Kechema	Jimma	Kechema	Jimma	Kechema	Jimma	Kechema
Mareko Fana	8.01^{efgh}	15.65^{a}	1.68^{def}	2.77^{a}	2.60^{ghij}	3.58^{cde}	1.04^{bc}	1.32^{a}
Bako Local	9.17^{defg}	13.55^{ab}	1.44^{efgh}	2.22^{bc}	3.59^{cde}	4.19^{bc}	0.85^{ef}	1.06^{bc}
Melka Zala	6.78^{ghi}	10.70^{cd}	1.71^{de}	1.40^{efgh}	3.27^{def}	6.75^{a}	0.11^{i}	0.43^{h}
Weldele	6.33^{hi}	9.08^{defg}	1.50^{efg}	1.50^{efg}	2.41^{hij}	3.55^{cde}	0.13^{ij}	0.67^{g}
Oda Haro	5.06^{i}	9.69^{def}	1.48^{efg}	1.14^{h}	3.55^{cde}	3.17^{defg}	0.51^{h}	0.77^{fg}
Melka Shote	7.08^{ghi}	10.37^{de}	1.23^{gh}	1.20^{gh}	2.70^{fghij}	2.81^{fghi}	0.51^{h}	0.51^{h}
Dube Medium	10.61^{d}	14.04^{ab}	$1,98^{cd}$	2.52^{ab}	2.18^{ij}	4.37^{b}	1.01^{cd}	0.92^{de}
Dube Short	7.42^{fghi}	14.67^{ab}	1.37^{fgh}	2.54^{ab}	2.97^{efgh}	4.37^{b}	0.84^{ef}	1.12^{b}
Gojeb Local	6.73^{ghi}	13.17^{bc}	1.38^{efgh}	1.96^{cd}	2.07^{j}	3.80^{bcd}	0.91^{de}	1.08^{bc}
LSD (0.05)	5.30		0.50		3.66		0.11	
CV (%)	0.50		12.70		13.12		19.08	

Values in each column sharing same letter are not significantly affected at ($\alpha = 0.05$)

4.4 Disease Incidence

Few of varieties were attacked by bacterial wilt (*Pseudomonas solanacearum*). Among the varieties attacked were Melka Shote, Melka Zala and Bako Local. There was also yield losses to some extent, the losses were less than 15.3, 6 and 5.3 percents at JUCAVM experimental field respectively. As to the control measures, besides the cultural control (avoiding weeds that harbor diseases, killing of the cut worms etc.), fungicide known as Mancozeb was sprayed for three rounds as a preventive activity: the first at vegetative growth, the second at pod setting stage and the third at green pod stage, and was practiced according to the label (EARO, 2004), but did not control the disease much. The base for this action was the high humidity due to continuous rainfall during the study period created a great fear for the prevalence of fungal, bacterial as well as viral diseases especially at Jimma experimental field.

4.5 Correlation

The present study showed that, the existence of significant and positive associations of yield and yield related traits with selected parameters. These include, the correlation between days to first harvest and number of flowers per plant (r=0.59**), between days to first harvest and fruit pericarp thickness (r=0.41*), between days to first harvest and shoot dry weight (r=0.45**), between days to first harvest and primary branches (r=0.56**), tertiary branches (r=0.61**) and fruit diameter (r=0.32*). Similarly, between number of flowers and seed per fruit (r=0.42*), between number of flowers and pericarp thickness (r=0.34*), shoot dry weight (r=0.68**), primary branches (r=0.69**) and tertiary branches (r=0.65**). Moreover, there was a significant and positive correlation between marketable yield and total yield (r=0.94***) between marketable yield and fruit diameter (r=0.27*.), between marketable yield and primary branches (r=0.72**), between fruit length and plant height (r=0.63**), There also existed a significant positive associations between fruit Pericarp thickness and marketable yield (r=0.35*) and fruit diameter (r=0.75**). (Appendix Table 6). This study is in agreement with Alee mullah *et al*. (2000), who reported that yield and quality were mainly dependant on the environment and or their inherent characteristics, which affects the traits simultaneously in same direction and some times in different directions.

As far as the ultimate goal of this study was to assess yielding potentials of the tested varieties, it will become evident that after economic and environmental justifications of the crop had been made, either of the parameters, i.e., days to 50% flowering, days to first harvest, canopy diameter, shoot dry weight, root dry weight, fruit dry weight and number of fruits per plant could be evaluated for better productivity of hot pepper for the future in the study area. Accordingly, variety Mareko Fana and Dube Short (with 1.32 and 1.25 t/ha, respectively) Marketable yield could be used by the growers of Jimma area while Mareko Fana, Dubbe medium and Dube Short that yielded 1.69, 1.49 and 1.46 t/ha, respectively, could be utilized by the growers in Seka area for better yield than the rest of hot pepper varieties evaluated during the study period.

5. SUMMARY AND CONCLUSIONS

Hot pepper is one of the major vegetable crops produced in South west Ethiopia, that serve as the source of income particularly for small holders in many parts of the study area. The yield of the crop is affected by the cultural practices, their genetic make-up and the growing environmental conditions existing in the study area. The objective of this study was to assess the effect of the growing environment on the hot pepper varieties, performance of the varieties and the interaction effect of location with varieties on growth, the dry pod yield and quality related characters during 2009-2010 dry season at Seka Chokorsa woreda Kechema nursery site and Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) experimental field. The study comprised (2 x 9) factorial combinations (locations and hot pepper varieties). The experiment was laid out in a split plot arranged in Randomized Complete Block Design (RCBD) with three replications.

The result of the study revealed that almost all of the parameters considered were significantly affected by the treatments or their interaction effects. Days to 50% flowering and days to first harvest were affected significantly by the growing environment and the variety itself. Accordingly, the shortest days to 50% flowering was obtained from variety Gojeb Local (46.67) and Mareko Fana (50.33 days) at Kechema nursery site, while the longest days to 50% flowering was recorded from variety Melka Zala (71 days) at JUCAVM experimental field. The earliest varieties to attain first harvest were Weldele (103 days) at Kechema, Mareko Fana (102.67 days), Dube Short (102.33 days) and Gojeb Local (66 days) at JUCAVM experimental field.

Fruit length and fruit dry weight exhibited significant difference for interaction effects of the locations and varieties. The highest records for parameters (fruit length and fruit dry weight) where, the highest fruit length was recorded from Mareko Fana (15.65 cm), Dube Short (14.67 cm), while the highest fruit dry weight was obtained from Melka Zala at Kechema experimental site. Yield related traits were also affected significantly by the interaction effect of varieties with the growing environment. Higher records of marketable yield were obtained from variety Weldele (1.93 t/ha) at Kechema, followed by Mareko Fana (1.69 t/ha), Dube medium (1.49 t/ha) and Dube Short (1.46t/ha) at the same location. Total dry fruit yield and the dry weight indicated significant difference among the varieties studied. The highest total dry fruit yield (2.02 and 2.18 t/ha) was recorded from variety Weldele at JUCAVM experimental field and Kechema nursery site, respectively, followed by Mareko Fana (1.89 and 2 t/ha) Dube Medium (1.69 and 1.72 t/ha) and Dube Short (1.46 and 1.82 t/ha), at JUCAVM experimental field and Kechema nursery site, respectively. Weldele with (72.33 fruits at Kechema) was the highest fruit yielder, followed by Mareko Fana (57.86 fruits) and Dube Medium (51.48 fruits) respectively at Kechema nursery site. However, Weldele has no consumer acceptance when compared with Mareko Fana, Dube Medium and Dube Short, due to its small pod size, light pod cooler and shrunken pod shape. Mareko Fana, Dube Medium and Dube Short with their uniform plant height and fruit length were found to have desirable pod size, thick pod skin and good shape, dark-red pod color preferred by consumers. They had low incidence of soil and air borne, as well as fungal and viral diseases as it has been observed at Jimma and Kechema locations during the study period, which were common problems of the crop in the study area.

Variety Mareko Fana and Dube Medium which produced 1.368 and 1.251 t/ha marketable yield, respectively appeared to be better varieties at JUCAVM experimental field, while Mareko Fana, Dube Medium and Dube Short with marketable yield of 1.698, 1.488 and 1.458 t/ ha, respectively, found to be better varieties at Kechema (Seka woreda) experimental site among the tested varieties. Such higher yield was attributed to the growing environment agro-ecological conditions (temperature, soil type, soil pH) and or due to the altitude difference or due to the heritable traits of these varieties. Moreover, the selection criteria of their marketable yield includes, long fruit size, thick fruit wall and dark-red pod color as a components of good quality which was highly demanded under Jimma condition. Furthermore, these varieties could be used for further research activities.

In general, the overall result of the present study indicated that the variety trial at different locations in the Jimma area substantially improve plant growth, the dry pod yield and quality of hot pepper to the benefits of the large scale producers in general and small scale producers in particular in the study area. However, as the study was the first of its kind in the study area, it would be advisable to further evaluate the varieties at different locations in the Jimma belt to establish sound production system for the crop. It appears to be worthy of considering further trials particularly:

- Variety evaluation in different potential areas of the Zone using different varieties (entries) of hot pepper.

- Since the study was done in the dry seasons, it is suggested to undertake the experiment during the rainy season at different locations.

- Absence of recommendations on rate of organic and inorganic fertilizers on hot pepper has been observed in the study area. Therefore, due attention needs to be given to conduct studies to determine rate of application for both types of fertilizers.

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7. APPENDICES

Appendix Table 1. Mean square values of days to 50% flowering, days to first harvest and canopy diameter as affected by interaction of location with variety in 2009/10

Source of variation	Degree of freedom	Plant height (cm)	Days to 50% flowering	Days to first harvest	Canopy diameter
Block	2	9.86^{ns}	60.96^{***}	17.57^{ns}	27.11***
Location	1	56.75**	18.96^{ns}	16502.52***	24.94^{***}
Block*Location	2	5.73^{ns}	24.04**	155.35ns	0.39^{ns}
Variety	8	120.43***	196.21***	753.39***	20.58***
Location*Variety	8	7.20^{ns}	27.96***	409.06***	6.65*
Error	32	5.93	7.20	54.07	2.78

ns=non significant,*= significant, **= highly significant, ***= very highly significant

Appendix Table 2. Mean square values of, primary, secondary, tertiary branches and Number of flowers per plant as affected by interaction between location and variety in 2009/10

Source of variations	Degree of freedom	Primary branches	Secondary branches	Tertiary branch	Number of flowers per plant
Block	2	0.55^{ns}	1.12^{ns}	29.71*	$50.51096n^{s}$
Location	1	147.28***	484.20***	2136.71***	39567.13***
Block*Location	2	8.83**	2.79^{ns}	10.42^{ns}	38.36^{ns}
Variety	8	5.22*	215.39***	30.057**	2045.24***
Location*variety	8	31.14*	24.25***	18.88*	2082.99***
Error	32	1.35	1.82	6.75	10.11

ns=non significant,*= significant, **= highly significant, ***= very highly significant

Appendix Table 3. Mean square values of, number of fruits, fruit length, fruit diameter and number of seeds per pod as affected by interaction of location with variety in 2009/10

Source of variations	Degree of freedom	Number of fruit per plant	Fruit length per plant.(cm)	Fruit diameter per plant (mm)	Number of seeds per fruit
Block	2	5.01^{ns}	0.12^{ns}	0.04^{ns}	15.78^{ns}
Location	1	269.03***	261.27***	2.03***	1801.78***
Block*Location	2	2.56^{ns}	0.46^{ns}	0.22^{ns}	8.11^{ns}
Variety	8	655.85***	17.087***	0.83***	2759.31***
Location*variety	8	157.73***	3.41*	0.49***	1331.05***
Error	32	15.95	2.22	0.05	44.26

ns=non significant,*= significant, **= highly significant***= very highly significant,

Appendix Table 4. Mean square values of, Seed weight, Pericarp thickness, Marketable yield and Unmarketable yield as affected by interaction of location with variety in 2009/10

Source of variations	Degree of freedom	Seed weight per pod.(g)	pericarp thickness (cm)	Marketable yield(t/ha)	Unmarketable yield (t/ha)
Block	2	0.01^{ns}	0.002^{ns}	3.198^{ns}	0.276*
Location	1	0.98***	1.77***	68.829***	4.347***
Block*Location	2	0.004^{ns}	0.004^{ns}	3.644^{ns}	0.259*
Variety	8	0.25*	0.46**	12.438***	0.379*
Location*variety	8	0.89***	0.35**	5.096**	0.104*
Error	32	0.01	0.004	10.20	0.31

ns=non significant,*= significant, **= highly significant, ***= very highly significant

Appendix Table 5. Mean square values of Total yield, Shoot, Root and fruit dry weight as affected by interaction of location with variety in 2009/10

Source of variations	Degree of freedom	Total yield (q/ha)	Shoot dry weight(g)	Root dry weight(g)	Fruit dry weight(g)
Block	2	13.765^{ns}	51.64^{ns}	12.80**	137.65^{ns}
Location	1	92.443***	1691.20***	1.75*	924.43**
Block*Location	2	48.826*	29.83^{ns}	0.09^{ns}	488.26**
Variety	8	17.602**	243.28**	9.96**	1766.02***
Location*variety	8	72.464***	80.44**	3.93*	724.64***
Error	32	72.73	12.88	0.23	72.73

ns=non significant,*= significant, **= highly significant, ***= very highly significant

Appendix Table 6. Correlation coefficients among parameters in hot pepper in Jimma and Kechema experimental site during 2009/10

	DFH	NFL	SPF	PCT	My	TDPY	SDW	FDW	PB	TB	PH	FL	FD
DFH													
NFL	0.59**												
SPF	-0.08	0.42*											
PCT	0.41*	0.34*	0.27*										
My	0.14	0.01	0.06	0.35*									
TDPY	0.14	0.04	0.06	0.27*	0.94***								
SDW	0.45*	0.68**	0.21*	-0.21*	0.26*	0.29*							
FDW	0.43*	0.36*	0.07	0.30*	0.18	0.14	0.29*						
PB	0.56**	0.69**	0.32*	0.25*	0.07	0.23*	0.55**	`0.32*					
TB	0.61**	0.65**	0.37*	0.24	0.03	0.08	0.54**	0.32*	0.72**				
PH	-0.01	-0.27*	0.40*	-0.06	0.12	0.23*	0.25*	0.40*	0.30*	0.47**			
FL	0.59**	0.59**	-0.60**	0.34*	0.64**	0.54**	0.20	0.11	0.18	0.51*	0.63**		
FD	0.32*	0.36*	0.31*	0.75**	0.27*	0.26*	0.20*	0.37*	0.24*	0.23*	0.05	0.63**	

DFH= days first harvest, NFL=number of flowers, SPF=seed per fruit, SWT=seed weight, PCT=pericarp thickness, MY=marketable yield (q/ha), UMY=unmarketable yield (q/ha), TDFRY= total dry fruit yield (q/ha), SDW= shoot dry weight,, FDW= fruit dry weight, PB=primary branch, TB=tertiary branch, PH=plant height, FL=fruit length, FD=fruit diamete

Appendix Table 7. Average vegetative and fruit characteristics of the test varieties

Varieties	Year of release	Altitude m.a.s,l	R/F(mm)	Soil type	Tempera ture	Pungen cy	Yield(q/ ha	Maturity days	Plant height (cm)	Fruit length (cm)	Fruit diameter(cm)	Pericarp thicknes s(mm)	Seed Sources
Mareko Fana	1976	1400-2000	600-1237	Sandy loam	20_29	high	15_20	120-135	60.2	11.3cm	2	2	MARC
Bako Local	1976	1400-2120	600-1237	Sandy loam	20_29	high	20_25	130_145	46.2	12.7	2.1	1	BARC
Melka Zala	2004	1200-2200	900-1200	Sandy loam	27/15	high	17_18	130_150	70	12.3	1.8	1	MARC
Weldele	2004	1000-2200	900-1300	Sandy\ loam	27/15	Very high	20-28	100	61	9.9	1.56	Nm	MARC
Oda Haro	2005	1400-2200	830-1559	agrisoil	13.3-27.9	medium	12.5	139	72	nm	nm	nm	BARC
Melka shote	2006	1000-2200	900-1300	Sandy loam	27/15	high	20-30	114	62	10.6	1.2	nm	MARC
Dube Medium	Under study	100-1200	600_1237	sandy loam	27/15	high	Nm	96	59	10.4	3.4	3	JARC
Dobe Short	Under study	100_1200	600_1237	sandy loam	27/15	high	Nm	96	62.6	13.1	2.5	1	JARC

Source: EARO, 2004; MARC, 2005

MARC=Melkasa Agricultural Research Center, BARC=Bako agricultural Research center, JARC=Jimma Agricultural Research Center, nm=not mentioned