

Growth and Yielding Potential of Hot Pepper Varieties under Rain-Fed Production at Woreta, Northwestern Ethiopia

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Abstract: Hot pepper is a widely grown vegetable, spice and condiment crop in Ethiopia, whose fruits are consumed as fresh, dried or processed products. It is also a major cash crop with high domestic- and export value. The use of unimproved local varieties of low quality and productivity, and soil borne and foliar diseases caused by fungi, bacteria and viruses are among several constraints the production system for green and dry pod confronted with. Field experiments were carried out to evaluate dynamics of growth, resistance /tolerance to disease and yielding potential of hot pepper varieties at Fogera Agricultural Research Center during the rainy seasons of 2014 and 2015. Five varieties namely, Markofana, Melkazala, Melkaawaze, Melkashote and a local check were laid in a randomized complete block design with three replications. The interaction between year and variety was found insignificant, where as varieties performed significantly different ($p < 0.05$) for most parameters considered in the study. The result revealed that varieties Melkazala and Melkaawaze were the most tolerant /resistant to disease attack with significantly ($p < 0.05$) high green pod yield of 13.00 and 14.53 ton per hectare, respectively. Besides promoting both Melkaawaze and Melkazala varieties for wide spread production in Fogera and other areas with similar agro-ecological conditions, the latter could also be used in breeding programs to transfer useful traits such as disease tolerance /resistance.

Keywords: *Capsicum*, disease, green pod, rain-fed, Woreta.

1. INTRODUCTION

Hot pepper (*Capsicum species*) belongs to the Solanaceae family and originated in the new world tropics and subtropics (Mexico, Central America and Andes of South America) over 2000 years ago (Walter, 1986 and Rodriguez *et al.*, 2008). The genus *Capsicum* consists of approximately 22 wild species and five domesticated species, which include *C. annum* L., *C. frutescens* L., *C. chinenses* L., *C. baccatum* L., and *C. pubescens* L. (Bosland and Votava, 2000, Patricia *et al.*, 2003 and Pickersgill, 1997). The *C. annum* complex, which includes three closely related species, *C. annum*, *C. frutescens* and *C. chinenses* are the most widely grown in the Americas and worldwide. *C. annum* has been domesticated in the highlands of Mexico, and includes most of the Mexican chilli peppers, most of the hot peppers in Africa and Asia and the various cultivars of sweet peppers grown in temperate countries. *C. frutescens* and *C. chinenses* are cultivated in Africa and Asia as spice crop, as intact fruits or for their oleoresin content. The other two species namely *C. baccatum* and *C. pubescens* are predominantly confined to Latin America (Pickersgill, 1997).

Peppers are grown extensively under various environmental and climatic conditions. It is an important cash crop for smallholder farmers in developing countries such as Ethiopia, Nigeria, Ghana, China, India, Pakistan, Bhutan, Indonesia, Cambodia, and Thailand (Lin *et al.*, 2013). In many countries of the world, pepper is a cash crop with high domestic- and export value. According to Lin *et al.* (2013), uses of pepper are generally grouped into five broad market categories: (i) fresh market (green, red, multi-color whole fruits), (ii) fresh processing (sauce, paste, canning, pickling), (iii) dried spice (whole fruits and powder), (iv) industrial extracts (paprika/ oleoresin, capsaicinoids and carotenoids) and (v) ornamental (plants and /or fruits).

Peppers are widely grown in various parts of Ethiopia and the fruits are consumed as fresh, dried or processed products, as vegetables, as spices or condiments. Today, the crop has not only attained economical, but also traditional importance. It is one component of the daily diet of Ethiopian people. Peppers are important in the local dishes as 'karia' (green pod), 'berbere' (fine powder from the dry

fruits of hot pepper), grinded mature green fruits blended with other spices and 'mitmita', the small very pungent fruits. The powder from dried ripe fruits of hot pepper is used as spice to flavor 'Wot', an Ethiopian stew in a daily traditional meal. Mature green pods ('karia') are eaten as salads.

Unless the sauce (stew) is 'alcha' (prepared without the use of hot pepper powder), 'berbere' is used daily in almost all Ethiopian house as a culinary spice in the preparation of stew (sauce) to yield the desired color, flavor and pungency. Fine pungent powder of hot pepper ('berbere') is an indispensable flavoring and coloring ingredient in the daily preparation of different types of Ethiopian sauces ('wot'), whereas the green pod is consumed as a vegetable with other food items (MARC, 2004). Green pods ('karia') are not eaten only fresh as vegetables, but also grinded and eaten with 'injera' (Ethiopian flat pancake prepared from grains of 'tef' (*Tef eragrostis*) or bread or with other food items and also used as ingredient of sauce. In all cases, powder of red pepper or grinded green pods is blended with other spices to add more color and flavor.

Pepper is a very important crop for spice extraction since it has a lot of Oleoresin for dyeing of food items and Ethiopia is among few developing countries that have been producing paprika and *capsicum* oleoresins for export market (MoARD, 2007). The crop is exported as dried ripe fruit or as oleoresin extracted from the fruits (Yosef and Yayehu, 1989). Today, small-scale farmers produce the largest proportion of hot pepper in the country. In many areas, pepper is grown predominantly as monocrop, and rotated with cereals or legumes, using the main rainy season. However, pockets of production in the dry season using irrigation can be found, particularly in the rift valley parts of Ethiopia.

Despite enormous uses of pepper as vegetable and spice, medicine, ornamental, and extensive pepper production practiced in Amhara region in particular and in Ethiopia in general, the production system for green and dry pod is confronted with several constraints. Absence of improved varieties and lack of pure seed supply are among major challenges of production. Zekarias (2012) reported that unimproved local varieties, namely marco (in Omo Nada) and kolesh (in Gojeb) are used in southwest Ethiopia, which attributed to low productivity and poor product quality. Farmers usually use local varieties of low quality seed with poor growth performance and low productivity. Susceptibility of local varieties to diseases is also among the major challenges of the production practice. Various diseases caused by viruses, bacteria and fungi and insect pests have emerged as serious threat of this crop in the major producing areas. Furthermore, the use of unimproved traditional horticultural husbandry such as fertilization are partly attributable to low productivity and quality. Shiferaw and Alemayehu (2014) indicated that a complex of diseases exist at each growth stage of hot pepper and the occurrence across districts was highly variable despite introduction and promotion of different management practices in southern Ethiopia. Pepper in Ethiopia can be produced both under rainfed and using irrigation. Valipour (2013) showed that 46% of the world is not suitable for rainfed agriculture and 80% of agricultural production is from rainfed areas, and further recommended agricultural integration is an affordable approach. According to Valipour (2012) determining critical periods and areas of water requirement is essential to increase productivity and water use efficiency.

Farmers use to grow mostly local selections, because there are shortages of improved varieties. Seeds are either from former harvests or bought from local markets. Such seed lots are often mixtures of different varieties with impurities harboring pathogens. Availability of varieties with high productivity and quality for 'bereber' (powder form) and green pepper that are widely adaptable and resistant/tolerant to major diseases and insect pests are lacking. Introduction and selection for best adaptable varieties with high yield and quality as well as resistant to biotic and abiotic environmental stresses is therefore a priority and quick approach to contribute towards alleviating major bottlenecks of the existing production system. According to Mskuwa *et al.*, (2016), introduction, domestication and commercialization of plants play a major role in improving rural livelihoods through nutritional status, household income, entrepreneurial opportunities and economic empowerment.

The use of unimproved local varieties of low quality and productivity, and soil borne and foliar diseases caused by fungi, bacteria and viruses are among several constraints the production system for green and dry pod confronted with. Varieties with high productivity and quality for dry pod (powder form) and green pepper that are widely adaptable and resistant/tolerant to major diseases and insect pests are lacking. As a result, production and productivity of pepper is declining and farmers are abandoning pepper production in many places around the study area. This growth performance and yielding potential evaluation of varieties was therefore undertaken to identify best varieties for

disease resistance /tolerance, high green pod yield and quality around Fogera district in Northwestern Ethiopia.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted at Fogera Agricultural Research Center during the rainy season of 2014 and 2015. The Center is found in Woreta town of Fogera district of South Gondar Administrative zone in Amhara Region, Ethiopia. Woreta lies at 11° 58' N latitude and 37° 41' E longitude. It has an altitude of 1819 m above sea level and receives average annual rainfall of 1230 mm. Mean minimum and maximum temperature of the area is 12 and 28⁰C, respectively. Soil of the site is red clay (vertisol) with a pH of 5.48.

2.2. Plant Material and Seedling Raising

Seeds of four improved hot pepper varieties, namely, Markofana, Melkazala, Melkaawaze and Melkashote were obtained from Melkassa agricultural research center of the Ethiopian Institute of Agricultural Research, and seeds of a local hot pepper were purchased from Woreta market. Seedlings of five varieties (four improved and one local) were raised in a nursery. Seedlings of each variety were raised on 2m x 1m (adjacent plots) thoroughly prepared beds, 5 cm raised from the surface (Figure 1). Seeds were drilled on rows with ten cm inter-row spacing and it was covered lightly with fine soil and mulched with dried grass until emergence. Weeding was accomplished as deemed necessary. Seedlings were thinned at first true leaf stage to allow sufficient distance within seedlings. Seeds for the first experiment were sown in a nursery on 21st May 2014 and transplanting in the field was made on 22nd July 2014 where as in the second year seeds were sown in a nursery on 21st May 2015 and transplanting in the field was made on 14th July 2015.

2.3. Experimental Design and Pre-Harvest Field Management

Experimental field was thoroughly plowed and leveled, and ridges were then prepared on sides of which transplanting was done (Figure 1). Experimental design employed to evaluate the performance of five varieties was randomized complete block with three replications. An effective plot size of 4.0 m by 3.6 m with 40 cm and 60 cm intra- and inter-row, respectively, spacing was used, accommodating 60 plants in six rows for each treatment. Gangways in between replications and plots were, in that order, 1.5 m and 1m wide. Both trials in 2014 and 2015 were carried out during the rainy period without supplementary irrigation.

Inorganic fertilizers in the form of Urea (46:0:0) and Diamonium phosphate (DAP) (18:46:0) both at the rate of 100 kg/ha (kilogram per hectare) were applied. DAP was applied at transplanting while urea is applied in two splits, the first at transplanting and the second one and half months from transplanting. Standard field management practices such as weeding and cultivation were performed uniformly during the growing seasons.

2.4. Data Collection

Disease incidence was regularly observed and recorded using one to five score where five refers to 100% attack, all leaves and plants developing severe symptoms. Seedling emergence, vigor and field establishment after transplanting were also observed. Data was collected on plant height at first harvest. It is measured from the soil surface up to the tip of main branch. A total of six consecutive harvests, at a week interval, were made from a plot. Fruit yield (green pod) was harvested at appropriate maturity time and weight was taken for each treatment. Harvested pods were categorized into marketable and non marketable fruits. Mature green pods with visible damages, cracks, blemishes and discoloration due to biotic and abiotic stresses were considered non marketable. Hundred pod weight was also recorded by randomly taking pods from marketable fruits. Data was subjected to analysis of variance using SAS software version 9.2 and least significance difference (LSD) was used to compare treatment means when there was statistically significant difference (P<0.05).

3. RESULT

Six consecutive harvests, at a week interval, were made from every plot of experiments executed in 2014 and 2015 growing seasons. The first harvest was made in the third week of October while the

last was made in the first week of December. Performance of varieties was significantly different ($P < 0.05$) for most parameters considered (disease, plant height, fresh fruit yield, 100 pod weight) in the study, while the interaction between year and varieties was found insignificant.

The highest total mean green pod yield in 2014 and in 2015 was obtained from variety Melkaawaze (13.734 and 15.323, respectively) while the lowest was from variety Markofana (Table 1).

Table 1. Mean green pod yield of hot pepper varieties in ton per hectare.

Variety	2014 growing season		2015 growing season		Combined	
	First three harvest	Total (six) harvest	First three harvest	Total (six) harvest	First three harvest	Total (six) harvest
Markofana	1.385 ^b	3.823 ^b	1.68 ^b	5.060 ^b	1.532 ^c	4.441 ^c
Melkazala	6.430 ^a	11.913 ^a	7.492 ^a	12.485 ^a	6.961 ^a	13.000 ^a
Melkaawaze	7.792 ^a	13.734 ^a	9.840 ^a	15.323 ^a	8.838 ^a	14.529 ^a
Melkashote	2.980 ^b	6.629 ^b	4.507 ^b	11.057 ^a	3.743 ^b	8.843 ^b
Local	2.263 ^b	5.317 ^b	2.731 ^b	5.416 ^b	2.497 ^{bc}	5.366 ^c
CV%		28.47	29.54	29.43	32.89	28.32
LSD(5%)	3.053	4.440	2.95	5.468	1.879	3.118
Interaction Variety*year	NS	NS	NS	NS	NS	NS

Means followed with the same letter within a column are not significantly different at $P < 0.05$.

Variety Melkazala had better tolerance /resistance to disease attack than variety Melkaawaze and significantly better than the other three varieties (Table 2). The major disease observed in 2014 and 2015 was bacterial leaf spot. Shiferaw and Alemayehu (2014) also showed that fungal (*Fusarium* wilt and powdery mildew) and bacterial (wilt, leaf spot and soft spot) and virus diseases are the most frequently encountered diseases in hot pepper producing areas of southern Ethiopia. Combined mean result showed that Melkaawaze was the tallest variety (70.15 cm) while local variety had the shortest height (47.95 cm) (Table 2).

Table 2. Mean disease score and plant height of hot pepper varieties.

Variety	Disease score (1-5 scale)			Plant height in cm		
	2014	2015	Combined	2014	2015	Combined
Markofana	1.50 ^b	1.50 ^c	1.50 ^c	55.47 ^b	52.97 ^{ab}	54.22 ^{bc}
Melkazala	0.37 ^a	0.50 ^a	0.43 ^a	70.20 ^a	56.00 ^{ab}	63.10 ^{ab}
Melkaawaze	0.83 ^a	1.00 ^b	0.92 ^a	71.47 ^a	68.83 ^a	70.15 ^a
Melkashote	1.50 ^b	1.50 ^c	1.50 ^c	48.30 ^b	56.93 ^{ab}	52.62 ^{bc}
Local	2.33 ^c	2.00 ^d	2.17 ^d	49.13 ^b	46.77 ^b	47.95 ^c
CV%	20.58	17.20	18.26	9.23	20.02	16.65
LSD(5%)	0.51	0.42	0.29	10.24	21.23	11.64
Interaction Variety*year	NS	NS	NS	NS	NS	NS

Means followed with different letters within a column are significantly different at $P < 0.05$.

Mean 100 green pod weight of variety Markofana and Melkazala was superior than the other three cultivars (Table 3). Mean pod weight in 2014 varied from 5.42 to 9.04 g where as in 2015 it ranged from 6.41 to 8.07 g. Overall mean pod weight depicted that the lowest pod weight was for variety Melkashote while the highest was for variety Melkazala. In agreement to the present finding, Awole *et al.* (2011) reported that mean pod weight of five pepper varieties to be in the range of 6.6 and 17g. Nsabiyea *et al.* (2012) also indicated that pepper genotypes varied from 1.1 - 16.2g in their mean fruit weight.

Table 3. Mean 100 green pod weight of hot pepper varieties.

Variety	100 green pod weight in gram		
	2014	2015	Combined
Markofana	842 ^{ab}	807	824 ^{ab}
Melkazala	904 ^a	788	846 ^a
Melkaawaze	661 ^{abc}	641	651 ^{bc}
Melkashote	542 ^c	659	601 ^c
Local	601 ^{bc}	656	628 ^c

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CV%	21.8	15.85	21.45
LSD(5%)	292	212	185
Interaction Variety*year	NS	NS	NS

Means followed with different letters within a column are significantly different at $P < 0.05$.

The highest percentage non marketable fruit was recorded from local variety (4.26%) in 2014, where as the lowest is from variety Markofana (0.33%). Similarly, local variety (4.5%) and Melkaawaze (4.4%) had the highest percentage non marketable fruit in 2015. Except for variety Melkashote, per cent non marketable pepper is higher in 2015 than in 2014 (Figure 2).

4. DISCUSSION

Combined mean green pod yield revealed that Variety Melkaawaze (14.529 ton) followed by Melkazala (13.0) produced significantly high pod yield than the other cultivars. In 2014 and 2015 growing seasons, the highest total green pod yield was obtained from variety Melkaawaze followed by Melkazala while the lowest yield was from variety Markofana (Table 1; Figure 3). This is associated with superior vegetative growth including height, and tolerance to disease attack. Although the highest green pod yield was obtained from variety Melkaawaze, it was not significantly different from the yield obtained from variety Melkazala (Table 1). Gebremeskel et al. (2015) also found that variety Melkaawaze was the highest yielding under irrigation at Raya valley, Tigray Ethiopia. It is therefore demonstrated that performance of Varieties Melkaawaze and Melkazala were superior in various locations with similar agro-climatic conditions. Moreover, these two varieties performed best both in the main season under rain fed production and in the dry season using irrigated production. It can therefore be inferred that these varieties are adaptable to wider locations including suitability to different production systems in the rainy season and during the dry period using irrigation.

In addition to varieties with specific adaptation for specific location, varieties with wide adaptation are crucial to Ethiopian situation with varied agro-ecological conditions. In many areas of the world including Ethiopia, water resources are limited and irrigation is not economical (Valipour, 2013). It is therefore indisputable to develop or identify varieties with high productivity and good quality under rain fed production.

Despite its good fruit quality for 'berbere' and 'karia', poor vegetative growth during the rainy season was observed from variety Markofana. Performance of variety Markofana was poor during the rainy season, reviving to flourish with good vegetative growth later in the end of the rainy season when other varieties started turning into good reproductive stage. Further vegetative growth of Markofana was however limited and dried prematurely due to absence of irrigation water supply during the dry season. This presumably reflected that this variety could be suitable to dry season production using irrigation.

Local variety was the most susceptible to disease attack and even symptom development started at seedling stage in the nursery. This is presumably attributable to the use of impure seeds harboring inoculums of pathogens. According to Shiferaw and Alemayehu (2014), out of 90 seed beds assessed in south Ethiopia, 55% of seed beds were infected by seedling diseases.

Slow growth at seedling stage from variety Melkazala was compensated with noticeably quick vegetative growth after field establishment and during the reproductive phase. Moreover, variety Melkazala had dark green foliage color and was the most tolerant variety to disease attack. Though insignificant when compared with variety Markofana, Melkazala had also the highest overall mean pod weight.

Tolerance / resistance to disease attack of these two varieties (Melkazala and Melkaawaze) accompanied with their best vegetative growth including height were attributable to their best performance in yield. In addition to direct promotion for widespread production of varieties Melkaawaze and Melkazala, the latter variety could preferably be used in breeding program to transfer disease tolerance /resistance traits. Since Melkazala had very slow seedling growth and generally slow vegetative growth at early stage, complementing parents for breeding could be those with fast growth habit at an early stage and /or good pod quality.

5. CONCLUSION

The use of disease infected seeds and seedlings and inoculums from the soil are causing complete failure of pepper plants at vegetative stage. Many farmers in Amhara region are therefore abandoning pepper production due largely to diseases caused by fungi and bacteria. It is a priority task to identify parental lines for launching breeding programs targeted to develop varieties with high yield, superior quality and resistance / tolerance to biotic and abiotic stresses. Furthermore, availing healthy seeds with high productivity and product quality is crucial. Varieties Melkazala and Melkaawaze had the best growth performance and were found the most tolerant to disease attack ultimately producing significantly high total green pod yield. These varieties could therefore be promoted for wide spread production by multiplying healthy and pure seeds.

Since Ethiopia has a diversified agro-ecology varying in climatic and edaphic conditions from location to location, research supported recommendations of varieties of wide and specific adaptation are essential. Variety Melkazala could be used in breeding program to transfer disease resistance /tolerant traits. Since Variety Melkazala is slow in growth characteristics at seedling stage, complementing parents could be those with fast growth habit at an early stage and /or good pod quality. Further development of varieties through breeding and promotion of improved varieties with high productivity and product quality, and resistance /tolerance to biotic and abiotic stresses are therefore indispensable.



Figure 1. Seedling raising and transplanted pepper on sides of ridges.

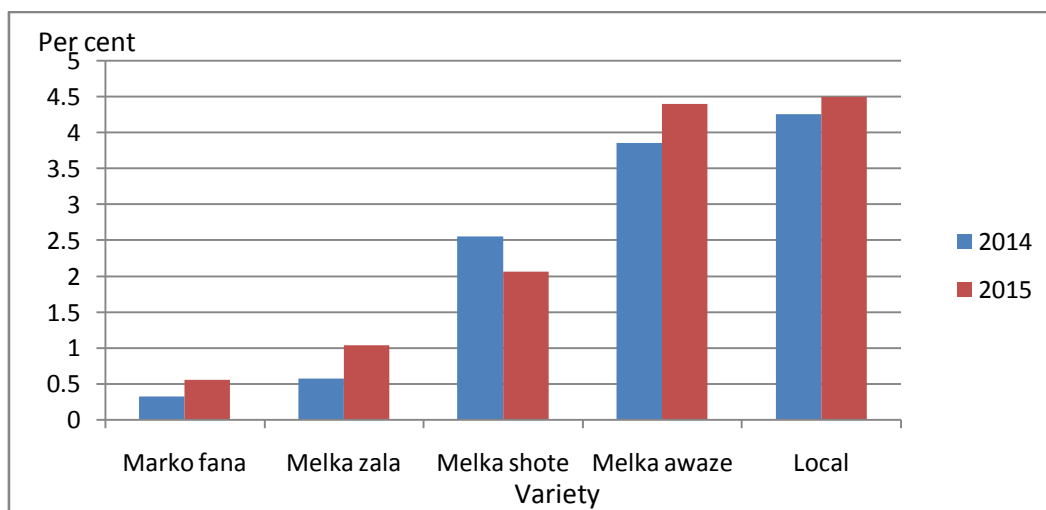


Figure 2. Mean percentage non marketable green pods.

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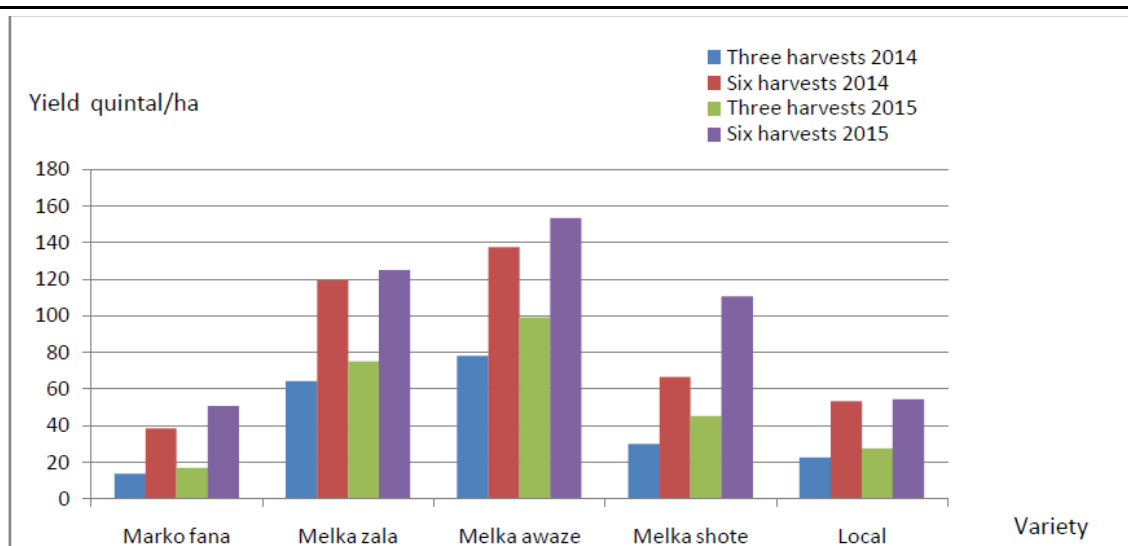


Figure 3. Mean total green pod yield in quintal per hectare.

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