

*Full Length Research Paper*

# **Response of hot pepper (*Capsicum annuum* L.) to major fungal diseases under field and greenhouse conditions in Horo Guduru Wollega, Oromia, Ethiopia.**

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Hot pepper (*Capsicum annuum* L.) is a national spice and vegetable of Ethiopia, produced as a cash crop. Biotic and abiotic stresses are very common throughout the pepper producing area of the country. Diseases are the major constraint to hot pepper production. An experimental trial was conducted at Harato Research site, Wollega University, Ethiopia to evaluate the reaction of five hot pepper varieties (Mareko Fana, Bako Local, Melka Shote, Melka Awaze and Oda Haro) and one local variety has control against the major fungal diseases. In vitro and in vivo, test was conducted during 2018/2019 main growing season. The result showed that *Phytophthora* blight (*Phytophthora capsici*) followed by, Frog-eye leaf spot (*Cercospora capsici*) and Fusarium wilt (*Fusarium oxysporum*) were the most predominant and severe fungal pathogens for hot pepper at the specified growing area. There was high significant ( $P < 0.001$ ) difference between varieties for all diseases scored, yield and yield components. Even though, the degree of infection varied between the varieties, the local checks were highly attacked by *Phytophthora* blight and Fusarium wilt whereas, Melka Shote and Melka Awaze varieties were devastated by Frog-eye leaf spot in both fields and greenhouse conditions. The tested varieties including traditional and improved varieties were affected by fungal pathogens and it is recommended to intensify research programs aimed at disease resistance and genetic improvement of cultivated hot pepper varieties through breeding procedures towards the interest of resource poor farmers.

**Key words:** Hot pepper varieties, fungal pathogens, response, yield and yield components.

## **INTRODUCTION**

Hot Pepper (*Capsicum annuum* L.) belongs to the family of Solanaceae that includes tomato, potato, tobacco, and petunia. It is the world's second most important vegetable crop ranking after tomatoes and is the most produced type of spice flavoring and coloring food while providing essential vitamins and minerals (Dias et al., 2013). It is

believed to have originated in Central and South America after which it spread into the New World Tropics before its subsequent introduction into Asia and Africa in 1493 (Bosland and Votava, 2000). Recent Carbon dating research indicates Mexico is the origin for hot pepper (Kraft et al., 2014). Pepper is growing worldwide in all the

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continents except Antarctica. There are stories about pepper been kept in flowerpots to spice up their food in Antarctica (Bosland and Votava, 2000). Hot pepper was introduced to Ethiopia in the 17th century by Portuguese (Huffnagel, 1961). However, its history in the country is perhaps the most ancient than the history of any other vegetable product (EEPA, 2003).

In Ethiopia hot pepper serves as high-value vegetable, spices and used in the form of dishes, fresh one “*karia*” and “*berbere*” proceed products. In the processing industries (coloring agent) locally and exported in the form of oleoresin (red pigment) and ground powder in different forms (Yemane Kahsay, 2017). The total area of hot pepper production for green pod was about 54,376 ha with the total production of about 770,349 quintals (CSA 2017/2018). The dry pod yield estimate in small holder farmer field was about 4q/ha, whereas in the state farm it is about 3q/ha. This variation in yield is due to lack of crop management practices for instance water application system that may facilitate disease development, lack of improved varieties, crop rotation, and harvesting system (MARC, 2005). Yield is dependent on varieties and varieties themselves are considerably dependent on several factors also (Fekadu et al., 2008).

In Western Ethiopia, small holder farmers are producing hot pepper as a spice and vegetable crop for food. Despite its uses in this area production and productivity of hot pepper are affected by the occurrence of many pathogens. The present situation indicates that the pathogens (Fungal, bacterial and viral) are devastating the crop at various growth stages from nursery to harvesting and significant yield loss is observed which limits the production of hot pepper by small holder farmers. Hot pepper is attacked by complex wilting disease caused by fungi such as blight (*Phytophthora capsici*), *Rhizoctonia* and *Fusarium spp.* Not only in Western Ethiopia, but also in the country as a whole (Gobie, 2019). The outbreak of Powdery mildew was also reported in southern Ethiopia (Belete et al., 2012). In addition to that, Pod rotting and Frog-eye leaf spot also known as *Cercospora* leaf spot (*Cercospora capsici*) was also an important disease with varying severity levels from three to five in the region of Ethiopia (Wondirad et al., 2009). Specifically, at Horo Guduru Wollega Zone no research has been done and data are limited on the status of hot pepper variety against major fungal disease. However, the area has high potential in the production of different vegetable crops besides hot pepper. Environmental condition is also favorable for easy emergence of a different pathogen. (André et al., 2018) a significant amount of Hot pepper damage and yield losses associated with various disease complexes like *Phytophthora blight*, *Fusarium wilt* disease and *Leaf spot* around Harato area and villages which have a potential pathogenicity to devastate hot pepper in a short period of time. Hence an attempt was made to evaluate different hot pepper varieties against these complex fungal

pathogens to identify the best performed varieties. Therefore, the objective of this paper was laid with response of different hot pepper varieties against major fungal diseases under open field and greenhouse conditions.

## MATERIALS AND METHODS

### Descriptions of the study area

The study was conducted at the research site of Wollega University farm land under rainfed condition. The area is located in Horo Guduru Wollega zone, Oromia National Regional State at about 300km in the west way from Addis Ababa with an altitude of 1800-2250 m.a.s.l. The annual rainfall ranges from 1900- 2100mm and the minimum and maximum annual temperature ranges from 19-23°C. The farming system of the area is characterized by mixed farming. The soil is classified as clay loam textural class. The distribution of rainfall is unimodal which is characterized by a prolonged wet season from June to September and a short dry spell of showers from mid-February to April. There is a long dry period from October to February.

### Description and Source of varieties

Table 1 shows the description and source of hot pepper varieties used for experiment

### Field experimental trial

Six varieties of hot pepper, comprising of five released varieties and one local check were used to study the reaction of major fungal pathogens on the farmers' field during 2018/19 main cropping season. Recommended agronomic managements were practiced to facilitate seedling growth and development (Lemma D, 1998). The plot size was 1.5 m x 3.5 m (with a total plot size of 5.25 m<sup>2</sup>) with five rows and five plants per row (total 25 plants per plot). The seedlings were transplanted on 56 days after sowing at 4-5 true leaf stage. A spacing of 30 cm between plants and 70 cm between rows was maintained. DAP fertilizer at 200 kg/ha was applied as side dressing during the transplanting operation and Urea fertilizer 100 kg/ha was applied in two splits, 50 kg during the time of transplanting and the rest 50 kg was applied on 15 days after transplanting (EARO, 2004).

### Treatments and experimental design

The reaction of the hot pepper varieties were studied through a Randomized Complete Block Design (RCBD) with three replications in a factorial arrangement at Harato research site. A local check variety was tested as control. Besides, a Complete Randomized design (CRD) for *in vitro* and *in vivo* test were used with three replication at the laboratory and greenhouse facility established at of Wollega University.

### Laboratory work

#### Isolation and Identification of the causal agents

To identify the causal agents responsible for the occurrence of fungal diseases of hot pepper in Horo Guduru Wollega site was

**Table 1.** Detailed summary of hot pepper varieties used for the experiment .

Varieties	Year of Release	Maintenance	Adaptation m.a.s.l	Temperature (°C)	Rainfall (mm)	Seed Source*
Melka Awaze	2006	MARC	1000-2200	15-27	900-1300	MARC
Melka Shote	2006	MARC	1000-2200	15-27	900-1300	MARC
Oda Haro	2005	BARC	1400-2200	14-28	830-1559	BARC
Mareko Fana	1976	MARC	1400-2200	20-29	600-1337	BARC
Bako Variety	1976	BARC	1400-2120	20-29	600-1237	BARC
Local (control)	-	-	-	-	-	Farmer's variety

\*MARC : Melkassa Agricultural Research Centre , BARC : Bako Agricultural Research Centre.

studied in the laboratory (Alcamo, 2011). For this purpose, the samples were collected from the stem, leaf and fruit parts of hot pepper plants showing the symptom of infection and transported to Plant Pathology Laboratory, Wollega University for identification of causal agents. Infected and healthy parts of the plant were segmented approximately in 2mm<sup>2</sup> and surface sterilized with 5% of sodium hypochlorite for 3 min. Then it was rinsed in three successive changes of sterile distilled water. The surface-sterilized sample was kept for 5 min in the laminar flow hood. Then the samples were placed on the potato dextrose agar (PDA) with streptomycin and incubated at 27°C for 7-10 days. When the mycelia emerge, the colonies were sub-cultured on to fresh sterile PDA to obtain pure culture and after 15 to 21 days the fungal cultures grown on PDA were aseptically taken using a sterile inoculating needle and examined. Identification of fungi was carried out under compound microscope at 400X magnifying lens to examine sporangia, conidia, spores and mycelia.

### Greenhouse

A structure, primarily of glass or sheets of clear plastic, in which temperature and humidity can be controlled for the cultivation or protection of plants. Greenhouses are allow for greater control over the growing environment of plants the key factors which may be controlled that include temperature, levels of light and shade, irrigation, fertilizer application, and atmospheric humidity. Greenhouses are often used for growing vegetables, flowers, fruits, and transplants.

### *Phytophthora capsici* Isolates, Inoculum preparation and host inoculation

*Phytophthora capsici* (WUFS1) which were isolated from Harato field experimental area were used for pathogenicity test on hot pepper variety under greenhouse. Six varieties of hot pepper were used for the study and each variety was shown in ten pots filled with 3:1:1 ratio (soil, sand and compost) sterilized in an oven dried at 121°C for 20 min. All agronomic practices were followed throughout the experiment uniformly for all varieties (Chernet and Zibelo, 2019).

For zoospore production from a three-week-old pure colony, mycelia plugs were removed from the medium and macerated with sterile distilled water for 30 s. Then it was added to water agar and placed under the fluorescent lights at room temperature to induce sporangial developments for additional 3 consecutive days. After 24 h, sporangia were chilled at 4°C for 1 h to induce zoospores release. The mycelia from each plate were washed by 20ml of distilled sterilized water and filtered through cheese cloth and a zoospore sample was counted using a haemocytometer (Koc and

Üstün, 2011).

Suspension of three isolates was prepared at a concentration of 2 x10<sup>4</sup> zoospore/ml adjusted and was injected to the crown of two months old seedlings by making a little injury/wound and the control variety was sprayed by distilled sterilized water. Cell concentration per ml was calculated by the dilution factor in which one large square x dilution factors x10<sup>4</sup>. Before inoculation, the pots were watered for 24 h and remained saturated to optimize the zoospore infection. After inoculation, the inoculated seedlings were covered by plastic bag to induce the humidity that was needed for zoospore infection and monitored once in every week after the symptoms able to be seen. The samples were re-isolated from the crown and the leaf parts on which the symptoms were perceptible followed by re-isolated pathogens under laboratory to compare with the initially isolated pathogens to confirm Koch's Postulate.

### Data collection

Starting from 30 days after transplanting, the plants were monitored every week interval for expression of disease symptoms to assess disease occurrence (Nsabiyera et al., 2012). Disease incidence and severity (Mengist et al., 2019) was recorded from nine plants in the three central rows at each plot every seven days interval after transplanting from each variety. These data were recorded starting from the onset of disease symptoms to the physiological maturity of the fruit when it changes its colour to its respective maturity. Disease incidence (DI) was calculated as the proportion of infected plants per plot that was expressed as a percentage (Galanihe et al., 2004).

Disease severity was rated based on rating scales developed for the disease identified. The standard rating scale for *Phytophthora capsici* and Fusarium wilt was scored by the AVRDC procedure in 0-5 rating scale (AVRDC Report, 2004). Frog eye leaf spot (*Cercospora capsici*) was rated using 0-9 scale (Galanihe et al., 2004). The disease severity Index (DSI) was calculated according to the formula below.

$$DSI = \sum \{(P \times Q)\} / (M \times N) \times 100$$

Where, P = severity score, Q = number of infected plants having the same score, M = Total number of plants observed, N = Maximum rating scale number, DS=disease severity index.

Disease severity was converted to Area under Disease Progress Curve (AUDPC) and calculated by the formula (Campbell and Madden, 1990).

$$AUDPC = \sum_{i=1}^{n-1} (y_i + y_{i+1} / 2)(t + 1 - t_i)$$

Where,  $y_i$  = disease severity at the  $i^{\text{th}}$  observation (in percentage),  $t_i$  = time (days) of the  $i^{\text{th}}$  observation,  $n$  = total number of observations,  $y_{i+1}$  = disease severity at the second observation, and  $t_{i+1}$  = second days of observation.

### Yield and yield component

Data were collected on yield and yield components viz., number of fruits per plant, fruit length, number of seeds per fruit, fresh fruit weight, dry fruit per plants, marketable fruits per plants and unmarketable fruits per plants.

### Data analysis

ANOVA assumptions were checked for each response variables and disease incidence, disease severity, area under the disease progress curve (AUDPC). The yield and yield components were subjected to analysis of variance (ANOVA). 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. The analysis was done using the general linear model (GLM) of statistical analysis using SAS computer package version 9.2 (SAS, 2008). Means of significant different treatments were compared using least significant difference test at 5% significance level (LSD<sub>0.05</sub>).

## RESULTS AND DISCUSSIONS

### Disease incidence

Phytophthora blight (*Phytophthora capsici*) exhibited highly significant ( $P < 0.001$ ) difference effect among hot pepper varieties. The highest infection rate (90%) was observed on both local variety and Oda Haro variety, whereas the lowest was registered on Melka Awaze (24.77% incidence) variety (Table 2). Frog-eye leaf spot (*Cercospora capsici*) infestation showed a highly significant ( $P < 0.0001$ ) difference among the varieties. Accordingly, the highest Frog-eye leaf spot incidence was recorded from Melka Awaze (74.13%) followed by Melka Shote (64.77%) varieties whereas; the lowest was registered from local variety (22.37%).

Fusarium wilt (*Fusarium oxysporum*) was also isolated as an important hot pepper disease. There was highly significant ( $P < 0.001$ ) difference among hot pepper varieties. Oda Haro variety was the most susceptible variety by Fusarium wilt infection (37.03%), whereas Melka Shote was less infected (18.44%).

Therefore, different amounts of Phytophthora blight, Frog-eye leaf spot and Fusarium wilt incidences were recorded among hot pepper varieties. This may be due to varietal characters originated from different genotypes which have different degree of susceptibility and resistance to those different pathogens. Additionally, continuous cultivation of the same vegetable crops belonging to *Solanaceae* family such as tomato and potato on the same field for consecutive years may

increase pathogen populations and accumulate inoculum sources used for infection. This need improved management strategies like crop rotation with other than *Solanaceous* crops to reduce the amount of yield loss due to fungal pathogen infections. Sudheendra (2005) observed that the average disease intensity varied in different genotypes owing to varied inoculum potential.

According to Raymond et al. (2005) the occurrence and development of Phytophthora blight (*Phytophthora capsici*) was found high on susceptible crop such as pepper, tomato and cucumber.

### Disease severity

Phytophthora blight (*Phytophthora capsici*) severity showed a high significant ( $P < 0.001$ ) difference among the varieties. Oda Haro variety scored the highest disease severity (52.90%) as compared to other varieties. Regarding to Frog-eye leaf spot caused by *Cercospora capsici*, the highest severity was scored from Melka Awaze followed by Melka Shote by 27.27 and 26.87%, respectively whereas, the lowest was recorded from local variety with 9.7%.

Fusarium wilt (*Fusarium oxysporum*) severity was also found highly significant ( $P < 0.001$ ) difference among the varieties (Table 2). Oda Haro followed by Local variety scored the highest severity of 30.53 and 24.37%, respectively while the lowest was registered from Melka Shote (9.97%).

The severity of Phytophthora blight, Frog-eye leaf spot and Fusarium wilt diseases on hot pepper varieties were varied from variety to variety.

Generally, local varieties were severely attacked by Phytophthora blight and Fusarium wilt at Harato field experimental trial while Melka Shote and Melka Awaze scored the lowest Fusarium wilt and Phytophthora blight disease severity.

However, these varieties were highly infected by Frog-eye leaf spot pathogen at the study sites.

This result also showed that different variety had different response to different pathogens' reaction according to its genetic makeup and it is in line with the work of Nsabiya et al. (2012); the authors also stated that *Cercospora* leaf spot (Frog eye leaf spot) severity indices were highly affected by genotypes rather than the season based on their studies in hot pepper under Uganda environment.

### Area under disease progress curve (AUDPC)

A highly significant ( $P < 0.0001$ ) difference among the Hot pepper varieties was observed in terms of the Area under Disease Progress Curve for the isolated pathogen (Table 2). Oda Haro followed by local variety recorded the highest Phytophthora blight (*Phytophthora capsici*)

**Table 2.** Varietal reaction of hot pepper to disease incidence, disease severity and area under disease progress curve of major fungal pathogens.

Variety	Disease incidence			Disease Severity			AUDPC		
	Phytophthora blight	Frogeye leaf spot	Fusarium wilt	Phytophthora blight	Frogeye leaf spot	Fusarium wilt	Phytophthora blight	Frogeye leaf spot	Fusarium wilt
MarekoFana	52.53 <sup>de</sup>	39.6 <sup>e-h</sup>	22.72 <sup>e-g</sup>	31.00 <sup>c-f</sup>	15.10 <sup>f-i</sup>	13.30 <sup>e-i</sup>	29.85 <sup>e-g</sup>	12.81 <sup>g-j</sup>	8.42
Melka Awaze	24.77 <sup>j</sup>	74.13 <sup>a</sup>	21.61 <sup>e-g</sup>	14.80 <sup>kl</sup>	27.27 <sup>ab</sup>	10.05 <sup>i</sup>	13.95 <sup>k-m</sup>	27.17 <sup>b</sup>	9.13 <sup>j-k</sup>
MelkaShote	32.9 <sup>h-j</sup>	64.77 <sup>a-c</sup>	18.44 <sup>g</sup>	23.50 <sup>fj</sup>	26.87 <sup>ab</sup>	9.97 <sup>i</sup>	19.41 <sup>i-l</sup>	24.30 <sup>bc</sup>	7.20 <sup>jk</sup>
Bako Variety	71.73 <sup>b</sup>	29.07 <sup>g-i</sup>	30.71 <sup>a-c</sup>	36.60 <sup>bc</sup>	11.13 <sup>i-k</sup>	20.19 <sup>b-d</sup>	25.97 <sup>f-i</sup>	8.79 <sup>jk</sup>	14.69 <sup>c-h</sup>
Local Variety	90 <sup>a</sup>	22.37 <sup>i</sup>	28.12 <sup>b-f</sup>	49.17 <sup>a</sup>	9.70 <sup>ik</sup>	24.37 <sup>ab</sup>	44.37 <sup>ab</sup>	6.77 <sup>k</sup>	24.37 <sup>ab</sup>
Oda Haro	90 <sup>a</sup>	25.23 <sup>hi</sup>	37.03 <sup>a</sup>	52.90 <sup>a</sup>	13.30 <sup>g-k</sup>	30.53 <sup>a</sup>	48.63 <sup>a</sup>	9.84 <sup>i-k</sup>	28.26 <sup>a</sup>
CV (%)	13.56	21.56	17.32	18.86	16.37	25.74	19.065	20.63	27.24
LSD (0.05)	10.36	14.53	7.69	8.66	4.72	6.7939	7.72	5.41	2.85
P- value	**	**	**	**	**	**	**	**	**

Means with the same letter is not significantly different within the columns

**Table 3.** Varietal response of hot pepper varieties to yield and yield parameters at Harato research site.

Variety	Number of fruits per plant (Count)	Number of seeds per fruit (Count)	Fruit Length (cm)	Fresh fruit weight (g)	Dry fruit per plant (g)	Marketable fruits (q/ha)	Unmarketable fruits per plant (g)
Mareko Fana	38.85 <sup>c</sup>	143.33 <sup>cd</sup>	8.90 <sup>c-g</sup>	27.37 <sup>b</sup>	145.50 <sup>b</sup>	67.29 <sup>a</sup>	4.00 <sup>kl</sup>
Melka Awaze	18.48 <sup>lm</sup>	121.00 <sup>hi</sup>	8.15 <sup>g-k</sup>	8.12 <sup>j-i</sup>	26.66 <sup>p</sup>	9.31 <sup>o</sup>	7.09 <sup>g-i</sup>
Melka Shote	15.55 <sup>no</sup>	71.17 <sup>no</sup>	7.39 <sup>i-l</sup>	6.05 <sup>k</sup>	18.96 <sup>q</sup>	7.96 <sup>o</sup>	3.98 <sup>kl</sup>
Bako variety	27.15 <sup>g</sup>	119.33 <sup>hi</sup>	9.79 <sup>bc</sup>	20.70 <sup>cd</sup>	59.85 <sup>ki</sup>	27.21 <sup>f-g</sup>	3.08 <sup>l</sup>
Oda Haro	17.80 <sup>l-m</sup>	94.67 <sup>k</sup>	8.90 <sup>c-g</sup>	10.72 <sup>h</sup>	47.3 <sup>l-m</sup>	19.92 <sup>j-l</sup>	5.23 <sup>j-l</sup>
Local variety (Control)	21.51 <sup>g</sup>	124.67 <sup>gh</sup>	7.28 <sup>j-l</sup>	13.77 <sup>g</sup>	23.97 <sup>p</sup>	9.18 <sup>o</sup>	6.86 <sup>h-l</sup>
CV (%)	5.33	3.98	7.92	9.43	2.62	9.41	26.87
LSD (0.05)	2.66	7.69	1.14	2.50	3.03	4.48	4.92
P- value	**	**	**	**	**	**	**

AUDPC value by 48.63 and 44.37 respectively, whereas Melka Awaze registered a lowest AUDPC (13.95). Highest AUDPC value for Frogeye leaf spot pathogen was registered on Melka Awaze followed by Melka Shote with 27.17 and 24.30 respectively. AUDPC for Fusarium wilt was recorded on hot pepper varieties at the study area. Accordingly, Oda Haro variety recorded the highest value of AUDPC for Fusarium wilt, whereas Melka Shote scored the lowest AUDPC value (28.26).

The various rate of reaction of hot pepper variety to major fungal disease in the field may be due to the degree of resistance and susceptibility of variety against different pathogens and pathogen populations in the field. According to Adipala et al. (2001) and Jalata et al. (2019) the high resistance reactions against the diseases could be due to genetic differences among genotypes, environmental conditions and composition in the pathogen population responsible for the different diseases. Belete et al. (2012) and Chernet and Zibelo (2019) stated that, the intensity of disease depends on

pepper genotypes, cultural practices and season.

### Yield and yield component variables

#### Number of fruits per plant

The number of fruits per plant was significantly ( $P < 0.0001$ ) different among hot pepper varieties at the study site. Accordingly, Mareko Fana produced the highest number of fruits per plant, while Melka Shote followed by Oda Haro variety produced the lowest number of fruits per plant of 38.85, 15.55 and 17.8 respectively (Table 3). This result shows that each genotype has a specific impact on the number of fruits per plant. Fekadu et al. (2003) confirms that the number of pods per plant differences were mainly based on genotypic variations and less influenced by environment. Jalata et al. (2019) are also in the same view in case of chickpea.

### **Fruit length (cm)**

The length of fruit was highly significantly ( $P < 0.0001$ ) different among hot pepper varieties. The highest fruit length was registered from Bako variety (9.79 cm) followed by Mareko Fana while the lowest one was produced from local variety with (7.28 cm.) respectively (Table 3). This is in lined with the findings of Sileshi (2011) who stated that Mareko Fana was recorded the highest fruit length (15.65cm) at Harato Research Site and Amare et al. (2013) reports that the maximum pod length (8.29cm) was obtained from the variety of Mareko Fana at Bure Northwestern Ethiopia. This variation may be due to genetic makeup of the varieties.

### **Number of seeds per fruit**

Number of seeds per fruit was highly significantly ( $P < 0.0001$ ) different among the varieties. The highest number of seeds per fruit was counted from Mareko Fana whereas the lowest one was produced from Melka shote (Table 3). Accordingly, Mareko Fana variety produced the highest number of seeds per fruit (143.33) while Melka Shote gave the lowest number of seeds per fruit (71.17) at study area. This result is in lined with the findings of Aleemulah et al. (2000), who observed positive relationship between seed number and pod size. Obidiebube et al. (2012), found that there were varietal differences in the cultivars used even though the same type of fertilizer was applied at the same time and at the same rate in number of fruits per plant, fresh fruit and dry fruit per plant in four cultivars of pepper.

### **Weight of fresh fruit per plant (g)**

There was a highly significant ( $P < 0.0001$ ) difference in fresh fruit weight among varieties. Accordingly, the highest fresh fruit weight per plant was produced by Mareko Fana (27.37g) followed by Bako Local (20.7g) in the study area. Milka Shote registered the lowest fresh weight (6.05g). This result indicates that, Mareko Fana variety had a good performance in fresh fruit weight. This finding agrees with the work of Amare et al. (2013) that the highest record for fresh fruit yield was registered by variety Mareko Fana ( $10.92 \text{ t ha}^{-1}$ ) at Bure North Western Ethiopia.

### **Dry fruit weight per plant (g)**

The weight of dry fruit yield per plant was highly significantly ( $P < 0.001$ ) different between the varieties. The highest dry fruit weight per plant was registered from Mareko Fana (145.50g) while the lowest one was obtained from Melka Shote (18.96g). The genetic characters and pathogen infection resulted in the

variation of dry fruit yield between the varieties. Belete et al. (2012) determined the relationship between characters affecting optimum output which are very important for increasing yield in pepper genotypes.

### **Marketable Fruit yield (q/ha)**

Marketable fruit yield per hectare was highly significantly different ( $P < 0.0001$ ) among the varieties. The marketable fruit yield ranged from 7.96 q/ha to 67.29 q/ha. Mareko Fana variety gave the highest marketable fruit yield (67.29 q/ha) whereas Melka Shote (7.96 kg/ha) and Melka Awaze (9.31q/ha) yielded the lowest amount of marketable fruit yield.

The difference between marketable yields between the varieties may be due to the genetic characters of hot pepper variety and disease infection. Amare et al. 2013, who states that the highest marketable yield ( $1.91 \text{ t ha}^{-1}$ ) was obtained from variety Mareko Fana in a study conducted at Bure North Western Ethiopia.

### **Unmarketable fruits per plant (g)**

Unmarketable fruits per plant was highly significantly different ( $P < 0.0001$ ) among the varieties. Melka Awaze variety produced the highest mean of unmarketable fruit (7.09g) while the lowest one was produced from Bako Local variety (3.08g) at the experimental area. This finding is in line with Nsabiyeera et al. (2012) who outlined that a number of factors were observed to cause unmarketability of fruits, including physiological factors, biotic factors and genetic makeup of the varieties.

## **Laboratory work**

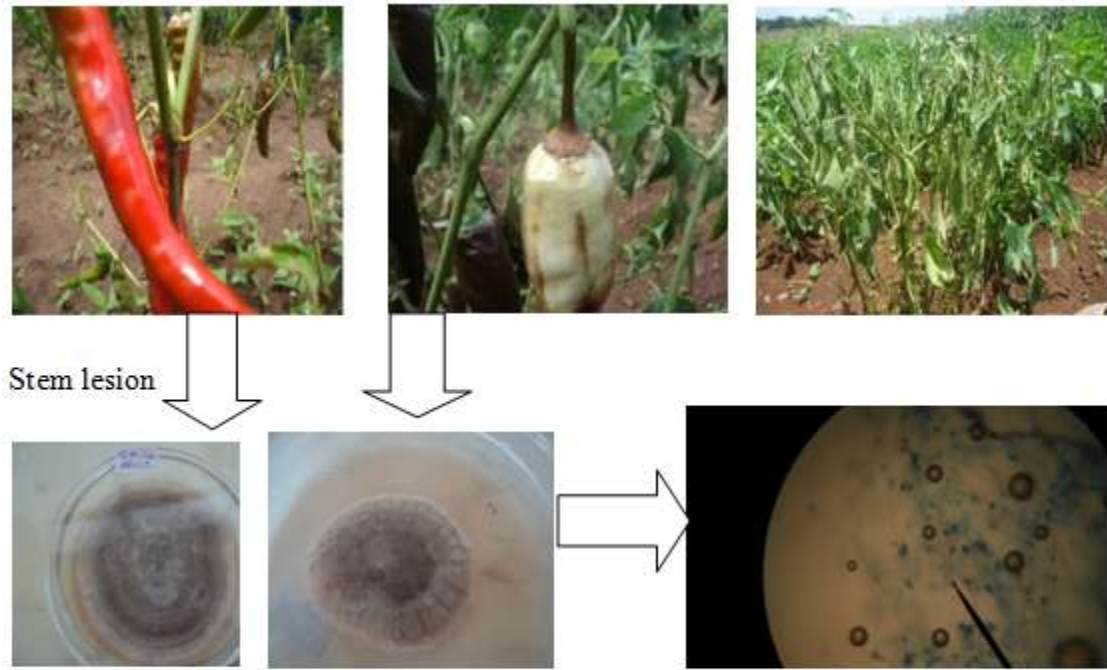
### **Isolation and identification of the causal pathogen**

Phytophthora blight, Frog-eye leaf spot, Fusarium wilt, *Alternaria* spp. and Powdery mildew were identified under *in vitro* condition. Accordingly, Phytophthora blight (*Phytophthora capsici*), Frog-eye leaf spot (*Cercospora capsici*), Fusarium wilt (*F.oxysporum*) were the most abundantly identified fungal pathogens. *P.capsici* was isolated from stem, leaf and fruit parts of a Hot pepper plant across the locations. Figure 1 to 5 explains symptoms of infection under field condition during survey and isolated pathogens under laboratory.

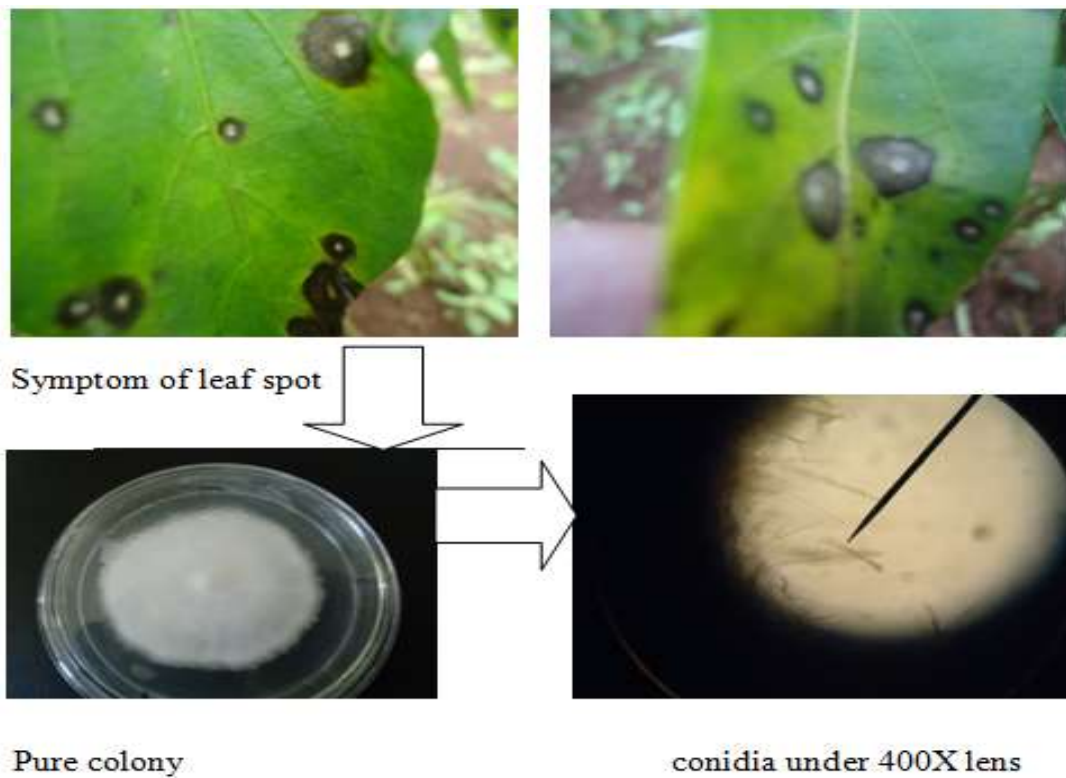
## **Greenhouse work**

### **Pathogenicity test**

A high significant ( $P < 0.001$ ) difference was observed among the isolates in terms of disease severity. Local



**Figure 1.** *Phytophthora capsici* isolated from Harato field experimental trial from local hot pepper (From stem part).



**Figure 2.** Frogeye leaf spot isolated from hot pepper at Harato field experimental trial



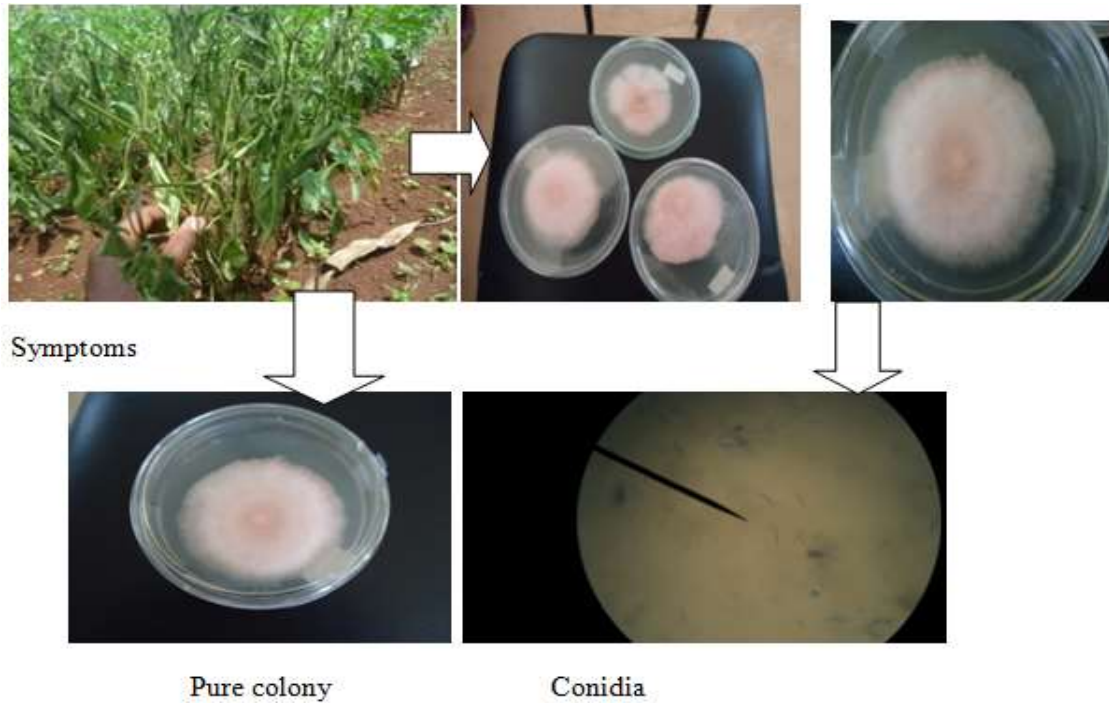


Figure 3. *Fusarium* wilt isolated from hot pepper at Harato field trial.

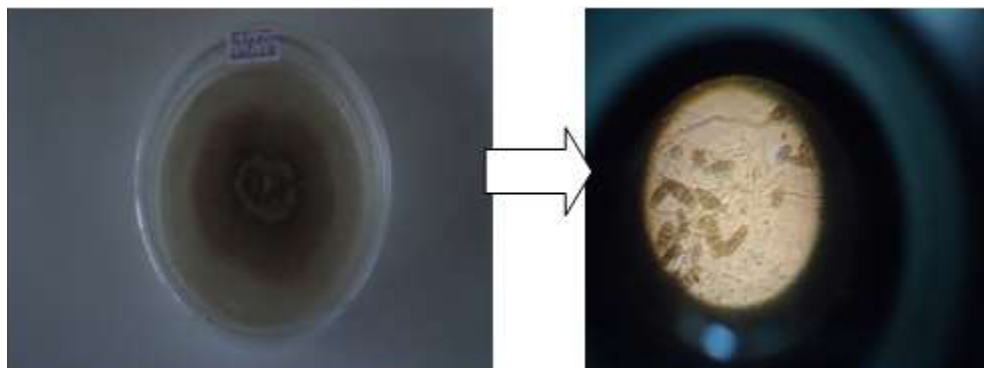


Figure 5. Artificially inoculated hot pepper and re-isolated colony.



**Table 4.** Severity of *Phytophthora capsici* inoculated on the hot pepper varieties under green house.

Isolates Name	Variety	Severity (%)
WUHF1	Mareko Fana	58.33 <sup>b</sup>
WUHF1	Melka Awaze	46.5 <sup>d</sup>
WUHF1	MelkaShote	46.5 <sup>d</sup>
WUHF1	Bako variety	50.5 <sup>c</sup>
WUHF1	Local Variety	77.5 <sup>a</sup>
WUHF1	Oda Haro	50.5 <sup>c</sup>
CV (%)		13.975
LSD <sub>0.05</sub>		3.55
P-value		0.001

Means with the same letter is not significantly different.

variety was severely attacked following the inoculation of WUHF1 isolate (Table 4). Disease severity ranged between 46.5% -77.5% in all varieties. However, the highest disease severity was recorded on Local variety inoculated with isolated WUHF1 (77.5%), whereas the lowest disease severity was observed on Melka shote and Melka Awaze (46.5%).

This result indicates that different *Phytophthora capsici* isolates exhibited pathogenic variability among the Hot pepper varieties. Din et al. (2013) stated that the isolates of *Phytophthora capsici* collected from different locations exhibited pathogenic variability among themselves. Islam et al. (2005) found significant differences among six *Phytophthora* isolates, when they inoculated pumpkin seedlings in the greenhouse.

## Conclusion

Hot pepper is one of the important vegetable crops produced in Western Ethiopia, which serves as the source of income particularly for small holders in many parts of the study area. Even though hot pepper yield losses due to fungal pathogen are not clearly quantified, complex disease caused by fungus is the major setback on quality and quantity of hot pepper production. The yield of the crop is affected by biotic, cultural practices, the genetic make-up and the growing environmental conditions existing in the study area. The major infectious diseases of Hot pepper include fungi, bacteria and virus. Fungal disease like *Phytophthora* blight (*Phytophthora capsici*), Frog-eye leaf spot (*Cercospora capsici*) and Fusarium wilt disease are the major pathogens identified in the study area.

The response of different hot pepper varieties towards those fungal pathogens was entirely different, that may determine the tolerability or susceptibility of variety and correspondingly virulence or avirulences of pathogens.

From the experimental trial it is observed that local varieties were the most devastated varieties by

*Phytophthora* blight (*Phytophthora capsici*) and scores highest incidences and severity. Similarly, the released variety (Oda Haro) was found highly susceptible to this pathogen also. Likewise, Melka Shote and Melka Awaze varieties were the most infected variety to Frog-eye leaf spot (*Cercospora capsici*) than the local check. *Phytophthora* blight isolates from Harato research site exhibited varied infection rates to hot pepper varieties under greenhouse during pathogenicity test. Generally, all the tested varieties showed differential characters to different pathogens both under open field and green house condition.

In terms of yield and yield component parameters, Mareko Fana variety gave the highest number of fruits per plant, dry fruit per plant and marketable fruit yield per plant followed by Bako local at the study area whereas Melka shote and Melka Awaze were produced less amount of hot pepper yield comparatively with the released one.

Intensive multi location studies across the study belt are suggested for a sound response of hot pepper varieties to major fungal and other diseases. Nearly all the tested varieties were affected by fungal pathogens at the study location. Therefore, in prospect, it is good to intensify research programs on disease resistance and genetic improvement of cultivated Hot pepper varieties through breeding.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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