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Growth and Yield Response of Hot Pepper (*Capsicum annuum* L.) to Varieties in Buno Bedele and Ilubabor Zone, Southwestern, Ethiopia

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Abstract: Low productivity of Hot pepper in Ethiopia was associated with different factors among which lack of well adapted varieties are most important ones in the area. Thus, adaptation trial of hot pepper varieties were conducted in Buno Bedele and Ilubabor zone with the objective of evaluating the performance and adaptability of introduced and improved varieties in different Hot pepper varieties. Four hot pepper varieties including local check were studied for their vegetative growth performance and pod yield under rain fed conditions in Randomized Complete Block Design with three replications. Data on different important characters were collected and analyzed using SAS Software of 9.4 version. Thus, combined analysis of data revealed that, varieties showed highly significant at ($P < 0.01$) for all collected parameters. The longest days to maturity (126.67 days) was recorded from Oda haro while the shortest days to maturity (117.67 days) was recorded from Local variety. Beside, the highest Pod number per plant (71.38) was recorded by Melka shote variety and the lowest Pod number per plant (39.87) was recorded from Oda haro. The longest (10.60) and the shortest (8.14) Pod length was recorded from Oda haro and Melka awaze varieties respectively. More wider (1.25cm) and more narrower (0.80cm) Pod diameter were recorded from Oda haro and Melka shote varieties respectively. More over the highest (3.80 t ha^{-1}) and the lowest (2.32 t ha^{-1}) Pod yield was recorded from Melka shote and Local varieties, respectively. Melka shote and Melka awaze varieties were resistant to disease (5r) than other varieties. However Oda haro and Local varieties were moderately susceptible (40ms) and moderately resistant (30mr) respectively. The result of the correlation analysis also revealed that Pod number and Branch number were significantly and positively correlated with Marketable and Total pod yield. Likewise Marketable pod yield was also significantly and positively correlated with Total pod yield. Thus, Melka shote and Melka awaze were varieties showed better performance with their mean yield and yield component. Therefore, these two varieties are recommended to be demonstrated on farmer's field for further scaling up.

Keywords: Disease Incidence, Hot Pepper, Marketable Pod Yield, Melka Shote Variety

1. Introduction

Hot pepper belongs to the family of Solanaceae and originated tropics and subtropics [1]. It is the second most important next to tomato in globe [2]. Hot pepper is high-value crop important in the local dishes, Karia, berbere, and processing industries as a coloring agent and raw material for the export market in the form of oleoresin [3]. It was introduced to Ethiopia by the Portuguese in the 17th century [4].

Agro-climatic conditions of Ethiopia are suitable for production of hot pepper in both rain-fed and irrigated conditions [5]. In Ethiopia, hot pepper is are usually grown at an altitude of 1400 to 1900 meter above sea level. For most Ethiopians food is testless without Hot pepper ; thus why it produced in many parts of the country. For the reason that it is wide received in the Ethiopian diet, it is crucial common crop mostly used for its spiciness and color [6]. The production of red pepper and green pepper are 1.59 t ha^{-1} and 4.95 t ha^{-1} in Ethiopia respectively [7]. Buno bedele and

Ilubabor zones are potential area for hot pepper production. Report of CSA [7] revealed that 3,395.25 and 9,809.69 hector of land is covered by hot pepper in 2022 cropping season. The Average productivities in Bunno bedele and Ilubabor zones is 1.58 and 1.74 t ha^{-1} respectively which is lower than both the national and regional production [7].

Low productivity is due to many limiting factors among which absence of improved varieties are among major challenges. Thus, farmers regularly use local varieties of low quality seed with poor growth performance, susceptible to diseases and low productivity. One of the efforts in reducing the yield and quality gap for hot pepper is the evaluation of the existing varieties, which enables the growers to select better adaptive varieties. Currently, no effort was made to advise agro ecologically adaptable, better quality and high yielding pepper variety for the specific area. Thus, the objective of this tudy was to evaluate and select better adapted Hot pepper varieties for fruit yield and Fruit yield components for the study areas and other similar agro-ecologies.

2. Materials and Methods

2.1. Description of Study Area

The trial was conducted at Dabo Hana and Bure Districts districts during 2021-2022 main cropping seasons.

2.2. Dabo Hana District

Dabo Hana district located in Buno Bedele Zone, Oromia Region, Southwest Ethiopia which 519 km far from Addis Ababa and 36km from Bedele town. The district surrounded by West Wollega Zone in West, East Wollega Zone of Jimma Arjo district in the East, Chawaka District in North, Bedele district in South, Mako, and Dega districts. It is located with altitude ranging from 1791 to 1990 masl [8]. The minimum and maximum annual air temperatures are 12.9 and 25.8°C, respectively. According to FAO soil classification system [8], the predominant soil type in southwest Ethiopia in general and the study area in particular is Nitisols.

2.3. Bure District

Bure district located in Ilubabor zone of Oromia Regional state thant surrounded on the west by Kelem Welega zone, on the west by, on the northeast by Matu, on south by Nono, on the southwest by Gambela Region and on the southeast by Alee. According to Ethiopian traditional agro-climatic classification system, Bure is in the Kolla (lowland) agro-ecological zone. The elevation of Bure is 619 up to 1844 m above sea level. The mean annual rainfall and mean annual temperature of Bure districts are 1340mm and 220C respectively [9]. Agriculture is the main economic source of income in the study area.

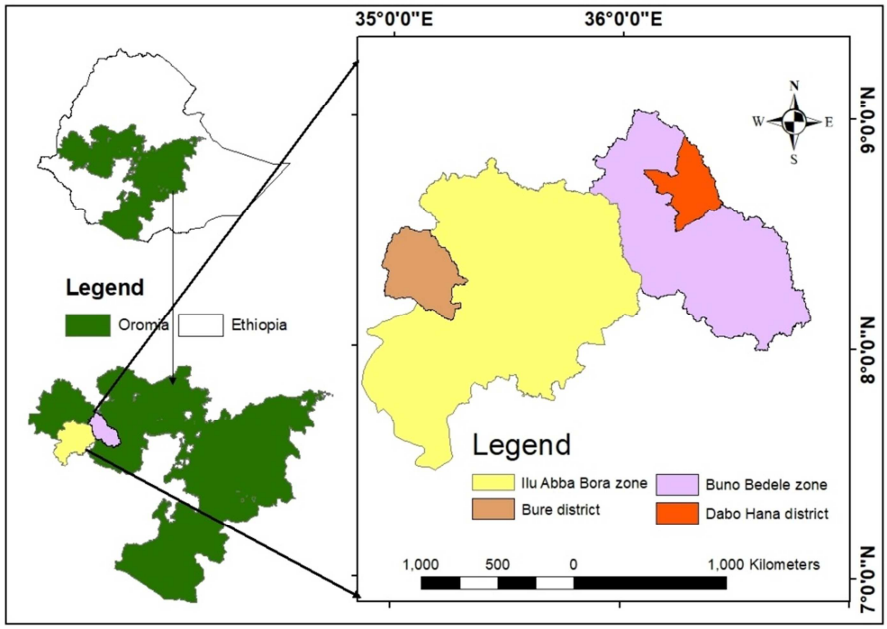

Figure1. *Mapof the study area.*

Table 1. *Description of Hot pepper varieties used in the experiment.*

No	Varity	Seedsource	Releasedyear	Altitude (masl)
1	Malkashote	MelkassaAgriculturalResearchCenter	2006	1000-2200
2	MalkaAwaze	MelkassaAgriculturalResearchCenter	2006	1000-2200
3	Odaharo	BakoAgriculturalResearchCenter	2005	1400-2200
4	Local-check	FarmersVarieties'	-	-

Source:(Kahsay, 2017)

2.4. Experimental Material, Treatments and Design

The experiment consists of four hot pepper varieties namely Melka Shote, Melka Awaze and and Oda haro obtained from Melkasa Agricultural Research Center and Bako Agricultural research center while farmers' variety (local) obtained from farmers for comparison. The design of the experiment was Randomized Complete Block Design in three replications. Each variety was planted in the main field in a gross plot size of 2.8m*2.4m with recommended spacing of 70cm and 30cm between rows and plants, respectively. The three middle rows were used for data collection leaving the two rows as borders. All agronomic practices (transplanting time, cultivation, and weeding and fertilization application) were applied uniformly for all plots according to the recommendation of the crop.

2.5. Raising and Transplanting Seedlings

Land preparation for the nursery bed was done using human labor. The seeds of the varieties were drilled by hand onto four nursery beds of 1 m width and 5m length at the inter-row spacing of 8 cm [5]. After sowing, the beds were covered with dry grass mulch until seedlings and water was applied using watering cans regularly. All management practices (fertilizing, watering, weeding, pest control, etc) were applied as required [5]. Additionally, prior to lifting, plots were watered to facilitate easy lifting of the seedlings and prevent too much root damage [1]. Transplanting was done on ridges were prepared at a spacing of 70 x 30 cm. During transplanting uniform, healthy and vigorous seedlings and having 20-25 cm height were selected and transplanted after 45 days from sowing [11]. Seedling gap filling was done within a week after transplanting.

2.6. Data Collection and Analysis

All phonological, growth and yield parameters of hot pepper data were collected based on the standard procedures described by [12] from the central three rows with net plot area of 3.78m^2 (2.1m x 1.8m). Data were collected using the standard procedures as described below.

2.7. Data Collected on Plot Basis

Days to 50% Flowering (Days): The number of days from the date of transplanting up to the date of 50% plant in the plot started flowering were counted and the mean values were computed and used for further analysis.

Days to 90% Maturity (Days): Hot peppers are physiologically matured when the pods had firm to touch, had a thick wall, shiny and waxy skin had firm thick wall to touch and deep green [13]. Accordingly, the number of days from the date of transplanting up to the date when 90% of the plants in the plot area attained at least one physiologically matured pods were counted.

Plant Height (cm): Plant height was measured from the soil surface to the top most growth points of above ground plant part [12]. The measurement was taken in centimeters from five randomly selected plants in the net plot area

Number of Branches Per Plant (Count): The number of primary and secondary branches counted from five randomly selected plants grown in the net plot area was recorded at first harvest and the mean value were computed and used for further analysis.

Number of Pods Per Plant (Count): The number of pods per plant was counted from five randomly selected and tagged plants grown in the net plot area and mean values were computed.

Pod Length (cm): Average lengths measured from tip of the fruit to basal end of five randomly selected marketable pods from the net plot area at each harvest were recorded and mean value was computed.

Pod Diameter (cm): Average diameter five of randomly selected marketable pods from the net plot area was measured at the middle of each pod at each harvest and mean value was computed.

Marketable Pod Yield (t ha^{-1}): Pods which are uniform in color, shape and size, free from damages, insect pest and disease attacks and physiological disorder like blemish were considered as marketable pods [14]. Such pods that are harvested in the net plot area during each successive harvest were weighed using sensitive balance after drying. The summation of each harvest was then converted to hectare basis and expressed in t ha^{-1}.

Unmarketable Pod Yield (t ha^{-1}): Pods which are visible damages, cracks, blemishes, discolorations and physiological disordered due to biotic and a biotic stresses, totally unwanted pods by consumers from marketable dried pods was recorded as unmarketable yield [5]. Such pods harvested from the net plot area during each successive harvest were weighed using sensitive balance and expressed in t ha^{-1}.

Total Pod Yield (t ha^{-1}): Sum of Marketable and Unmarketable pods from each successive harvest were measured and recorded to estimate total pod yield and expressed in t ha^{-1}.

2.8. Data Analysis

The collected data on different growth and yield parameters were subjected to the analysis of variance (ANOVA) using SAS Version 9.4 [15] and the interpretation was made following the procedure described by Gomez and Gomez [16]. Least Significance Difference (LSD) test at 5% probability level was used for treatment mean comparison when ANOVA shows significant differences. Correlation analysis was carried out by calculating simple linear correlation coefficients between growth and yield parameters.

3. Results

Combined Mean square for varieties were highly significant ($P<0.01$) for Days to flowering, Days to maturit, Number of pod yield, Plant height, Number of branch, Marketable yield, Unmarketable yield and Total pod yield

showed highly significant (p<0.01) (Table 2). This indicated that the presence of significant variations among varieties and the varieties had inconsistent performance over years.

Table 2. *Combined Mean square values on phenological and yield component response variables of Hot pepper verities 2022-2022 cropping season.*

SV	DF	DF	DM	PH	NPPP	BN	PL	PD	MY	TY
Rep	2	9.75ns	9.75ns	0.86ns	30.53ns	3.27ns	0.86ns	0.03ns	0.30	0.51ns
Var	3	160.69**	160.69**	76.66**	2245.26***	32.79**	76.66**	0.50**	7.62**	6.49**
Yr	1	3.52ns	3.52ns	9.76ns	2571.52***	24.54***	9.76ns	0.95***	0.19ns	5.04**
Loc	1	25.52ns	25.52ns	4.59ns	2159.14**	24.54**	4.588ns	0.04ns	8.15**	4.24**
Var*Yr	3	0.91ns	0.91ns	7.86ns	93.66ns	0.90ns	7.86ns	0.01ns	0.16ns	0.27ns
Var*Loc	3	0.91ns	0.91ns	7.95ns	102.86ns	0.90ns	7.95ns	0.01ns	0.16ns	0.18ns
Error	34	9.93	9.93	3.47	70.51	1.03	3.47	0.06	0.25	0.17
CV		4.17	2.25	7.13	27.43	15.25	23.58	21.31	24.02	14.47
Pvalue		**	**	**	**	**	**	**	**	**

Note: DF=Degree of freedom, DF=Days to flowering, DM= Days to maturity, NPPP = Number of pod per plant, PH = Plant height, BN=Branch Number, FL=Pod length, PD= Pod diameter, MY=Marketable yield, UMY= Unmarketable yield and TY=Total yield, CV=Coficient of variation **=highly significant at 5% and 1% respectively.

Days to 50% Flowering

The number of days to 50% flowering showed a highly significant (p<0.01) difference across varieties (Table 3). Accordingly, the longest (70.75day) and the shortest (62.17day) days to flowering was shown in Oda haro and local variety, respectively. This indicated that Oda haro took longer days to flowering while Melka shote flowered earlier. Earliness or lateness in the days to 50% flowering might have been due to the inherited characters, early acclimatization to the growing area to enhance their growth and developments [17]. This conclusion is consistent with the findings of who showed comparable ranges (60-72 days) for different varieties, including the cultivars used in the study. Kahsay [11] reported that the variation in the days to 50% could be probably due to their genetic factor, early acclimatization to the growing area.

Days to 50 % Maturity

Significant (P<0.01) variations were observed among the hot pepper varieties in the number of days to attain physiological maturity (Table 3). Oda haro required the longest time (126.67 days) until 50% of the plants to mature. Local varieties' required the shortest time (117.67 days) to mature. The results indicate that, the traits are affected by both genotype and environment. This might be due to the fact that maturity period is dependent on the varieties and climatic conditions. This is similar with the work of kahsay [11] who reported different maturity dates for different varieties.

Plant Height

Plant height significantly (P<0.01) influence due to Varieties (Table 3). Accordingly, Varieties Oda haro and Local had the tallest plant height (74.61cm and 72.94cm) respectively. While Melka Shote had the shortest Plant height (68.61cm). Similar results were reported by Zewde and Saa [18] said that when compare one variety to the other varieties used in the study area the varion of plant height observed between crop varieties.

Pod Number Per Plant

The significant difference in fruit number per plant of the varieties difference causes significant (p<0.01) difference in Pod number per plant (Table 3). The higher significant result was from the Melka shote variety (71.38) and followed by the Melka awaze variety (55.40) while Oda haro and Local Varieties produced less number of pod (39.87) than the others. The highest Pod number in Melka Shote variety was most likely due to the fruit bearing capacity of the variety and more branch formation nature which leads to contain high number of Pods per plant. Branch number strongly associated (r=0.87**) with pod number (Table 5). In line with this result, Yimer (2023) found different fruit number per plant due to variety differences. Furthermore, Elias and Biratu, [20] reported that number of Pods per plant was highly significantly affected by the interaction of variety by location.

Branch Number Per Plant

As shown in (Table 3), there was a variation in the branch number of different hot pepper varieties. As a result, Melka shote variety had the highest number of branches (9.05) based on the combined mean of two seasons when compared to the other varieties used in the study. While local showed significantly lower branch numbers (5.42 and 5.71 respectively (Table 3). Similar significant variations in the primary branch number of hot pepper varieties were also reported at Debremarkos University at the Zalima site [12].

Pod Length

The Pod length of the Hot pepper varieties significantly influenced (P<0.01) due the varietal effect (Table 3). The highest and lowest Pod length of Hot pepper variety was observed in Oda haro (10.55 cm) and Melka awaze (8.14cm) respectively. The significant difference in Pod length among the Hot pepper varieties attributed to the inherited traits and adaptability to the environmental condition of the study area. Again this current result was supported by the findings of [21].

Pod Diameter

The Pod diameter was a highly significant (p<0.01) difference between varieties (Table 3). The longest Pod diameter was recorded for the cultivar oda haro (1.25cm) followed by local (0.94cm). Melka Shote cultivar, on the other hand, had the smallest Pod diameter (0.80). This result

was in agreement with the finding of Assefa et al [17] found that Pod diameter was significantly affected due to varietal effect. Similarly, this was confirmed to the finding of Banjaw et al [23]which showed Marko fana produced the highest Pod diameter (1.98 cm).

Marketable Yield

The combined analysis of mean values showed significant variations in Marketable yields among Hot pepper varieties (Table 3). The maximum Marketable yield (3.32 t ha^{-1}) was obtained at Melka shote whereas the minimum Marketable yield (1.53 t ha^{-1}) was obtained at Oda haro (Table 3). The variation of marketable yield of these varieties could be due to difference in genetic characteristics and agro ecological adaptability nature and heritability is necessary in systematic improvement of hot pepper for fruit yield and related traits.

Disease Incidence

Phytophthora blight (*Phytophthora capsici*), Frog eye leaf spot (*Cercospora capsici*), Fusarium wilt (Fusarium oxysporum) and Powdery mildew (Leveillula taurica) were major disease observed on Hot pepper during the experimental period. Accordigly, variety Oda haro showed moderately susceptible (40ms) and local Moderately resistant (30 ms) (Table 3). However, variety Melka shote and Melka Awaze showed resistance (5r) to disease as compared to other varieties (Table 3). This variation in response to disease incidence is probably due to genetic variation in the susceptibility among the varieties.

Table 3. *Combinedmeanyieldandyieldrelatedparametersofhotpeppervarietiestestedduring2021-2022cropping season.*

Varieties	DF (Days)	DM (Days)	PH (cm)	NPPP	BNPP	PL (cm)	PD (cm)	MY (tha-^{1})	UMY(tha-^{1})	Disease
MalkaShote	64.42b	120.44b	68.61c	71.38a	9.05a	8.96b	0.80b	3.32a	0.50b	5r
MalkAwaze	64.92b	120.67b	72.10b	55.40b	6.45b	8.14b	0.87b	2.14b	0.54b	5R
OdaHaro	70.75a	126.67a	74.61a	39.87c	5.42cb	10.55a	1.25a	1.53c	0.86a	40ms
Local	62.17cb	117.67c	72.94b	54.47b	5.71cb	10.41a	0.94b	1.98b	0.34cb	30mr
LSD(0.05)	2.61	2.63	1.53	14.6	1.84	1.93	0.2	0.52	0.19	
CV(%)	4.17	2.25	7.13	27.43	15.23	23.58	21.31	24.02	28.52	
P-Value	**	**	***	**	**	**	**	***	***	

Note: DF=Days to flowering, DM= Days to maturity, PNPP = Pod number per plant, PH = Plant height, BNPP=Branch number per plant, PL=Pod length, PD= Pod diameter, MY=Marketable yield, UMY= Unmarketable yield and TY=Total yield, *** = Very highly significant,** = highly significant, LSD (5%)=least significant differences, CV = Coefficient of Variation and CV (0.5)= coefficient of variation, R=Resistance, MS=moderately susceptible and MR=Moderately resistant

Tota lPod Yield

Analysis of variance showed that there were highly significant (P<0.01) effect on total yield of hot pepper varieties (Table 4). Variety Melka shote had the highest total pod yield (3.80 t ha^{-1}) followed by variety Melka awaze (2.68 t ha-1) while variety Local and Oda haro had the lowest total pod yield (2.39 and 2.32 t ha^{-1}). The significance difference among varieties on total pod yield might be due to yield related parameters such as Branch number (r=99**), number of pods per plant (r=0.87**), Marketable yield (r=0.95**) and Umarketable yield (r=0.36**). This is in line with the findings of Sufiyan (2022) who reported the highest Pod yield of Melka Awaze variety at Raya valley of Northern Ethiopia.

Table 4. *Combined mean Pod yield (t ha-1) of hot pepper varieties tested in 2021-2022 cropping years.*

Varieties	Dabo Hanna			Bure	
	1 Year	2nd Year	Combined	1 Year	Over All
MalkaShote	2.69a	4.71a	3.70a	4.40a	3.80a
MalkAwaze	1.68b	3.22b	2.45b	3.20b	2.72a
OdaHaro	1.63b	2.73c	2.18b	2.79b	2.39b
Local	1.94b	2.54c	2.24b	2.55c	2.32b
LSD(0.05)	0.48	0.39	1.02	0.63	0.68
CV(%)	12.05	5.86	31.81	9.68	25.15
P-Value	**	***	*	***	***

CV=Coficient of variation,*** Very highly significant,** =highly significant and *= significant

Correlation Among Pod yield and Yield Contributing Parameters of Hot Varieties

Pearson correlation (r) of marketable pod yield with other traits revealed that marketable yield (t ha $^{-1}$) had highly significant positive correlation with pod number per plant (r=0.87**) and Branch number (r=0.99**). On the contrary, it had highly significant negative correlation with days to 50 % flowering (r=-0.24**) and 50 % Maturity (r= -0.24**) (Table 5). This indicated that pod number per plant and branch number are the most important traits in the specific agro ecology showed that any improvement in these traits increases total pod yield per hectare. This is in agreement with the finding of Tadesse and Bekele (2021) who report a highly significant positive association of pod yield ha^{-1} with pod weight, pod diameter and pod length. Similarly, Shushay *et al* [25] obtained a highly significant positive interrelation of single fruit weight with pod diameter.

Table 5. *Parson Correlation of Pod yield and yield related parameters in hot pepper varieties.*

	DF	DM	PNPP	PH	BNPP	PL	PD	MY	UMY	TY
DF	1									
DM	0.99**	1								
NF	-0.45**	-0.45**	1							
PH	0.44**	0.44**	-0.01ns	1						
BN	-0.24**	-0.24**	0.87**	0.23ns	1					
FL	0.41**	0.41**	-0.01ns	0.99**	0.22ns	1				
FD	0.26**	0.26**	-0.27**	0.37*	-0.05ns	0.37*	1			
MY	-0.40**	-0.40**	0.92**	0.07ns	0.95**	0.07ns	-0.26**	1		
UMY	-0.43*	-0.43*	0.06ns	0.54ns	0.36*	0.54ns	0.64**	0.06**	1	
TY	-0.24*	0.24*	0.87**	0.22ns	0.99**	0.22ns	-0.05ns	0.95**	0.36*	1

Note: DF=Days to flowering, DM= Days to maturity, PNPP = Pod number per plant, PH = Plant height, BNPP=Branch number per plant, FL=Pod length, PD= Pod diameter, MY=Marketable yield, UMY= Unmarketable yield and TY=Total yield, *=Significant and **=Highly significant at 5% and 1% respectively.

4. Discussion

The present results showed that the most important yield and yield contributing parameters: Days to flowering, Days to maturity, Plant height, Number of pod per plant, Pod length, Pod diameter, Marketable yield, Unmarketable yield and total Pod yield were significantly varied among the Hot pepper variety evaluated.

Accordingly, the longest days to flowering (70.75 days) and Days to maturity (126.67 days) were recorded from Oda haro variety while highest number of Pod per plant (71.38), Marketable yield (3.32 t ha^{-1}) and total pod yield (3.80 t ha^{-1}) were recorded from variety Melka shote variety. Pearson correlation (r) of Marketable pod yield with other traits revealed that marketable yield (t ha^{-1}) had highly significant positive correlation with pod number per plant (r=0.87**), Branch number (r=0.99**) and Marketable yield (r=95**).

5. Conclusion

Hot pepper is an important crop in Ethiopia. However, lack of research on Adaptability result in poor crop yields and high production costs in Ethiopia particularly to study area. Therefore, the ojective of this study was to come up with best adapting and disseminating this technology to local producers. The current investigation revealed, traits such as Plant height, Pod number per plant, Pod length, Pod diameter and Unmarketable yield were among the most important yield components which had highly significant positive association with marketable pod yield. Besides, Melka shote and Melka awaze were varieties showed better performance and resistant to disease with their mean yield and yield component.

Significance Statement

This study verified the possible the improved variety on the production and yield of hot pepper that can be beneficial for small and large-scale farmers and investors in the area of agriculture for business profitability. This research will also help the others researcher to further scale up the finding with different Agro-ecoloy.

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Conflicts of Interest

The authors declare no conflicts of interests.

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