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Research Article

Adaptation Trial of Small-Pod Chilli Pepper (*Capsicum frutescence* L.) Varieties in the Midland Areas of Guji Zone, Southern Ethiopia

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Abstract

Chilli pepper *(Capsicum species)* is one of the most important spices and cash crops produced in Ethiopia. However, information related to the potential of the midland areas of the Guji zone for Chilli pepper production is limited. This experiment was conducted in Kiltu Sorsa, Gobicha, and Derartu at three farmers' fields to evaluate the growth and yield performance of Chilli pepper varieties and to select and recommend high-yielding Chilli pepper varieties. Five improved Chilli pepper varieties (Kume, Melka dera, Melka oli, Dinsire, and Dame) and one local check were evaluated. The treatments were arranged in a Randomized Completed Block Design (RCBD) with three replications. The result of statically analysis indicated significant differences (P<0.05) among the Chilli pepper varieties for days to 90% maturity, pod length, pod diameter, unmarketable red dry pod yield, and marketable red dry and green pod yield. The highest marketable dry red and dry pod yields were recorded from Melka Oli (23.16 qt/ha), followed by Melka Dera (19.32 qt/ha), respectively. But the lowest marketable dry red pod yield (12.72 qt/ha) was obtained from a local check Chilli pepper variety. Therefore, two improved Chilli pepper varieties, i.e., Melka Oli and Melka Dera, are selected and recommended for midland areas of the Guji zone.

Keywords: Adaptation; Chilli pepper; Improved variety; Spice

Introduction

Pepper is the world's most important vegetable after tomato and used as fresh, dried or processed products, as vegetables and as spices or condiments [1]. It's a new world crop that belongs to the *Solanaceae* family, and the genus *Capsicum.* It is closely related to tomato, eggplant, potato and tobacco. The genus *Capsicum* is the second most important vegetable crop of the family after tomato in the world [4]. Chilli pepper spread rapidly across Europe into India, China, and Japan. Since its discovery by Columbus, the crop has been incorporated into most of the world's cuisines [8]. The crop is a national spice of Ethiopia and believed to be introduced to Ethiopia probably by the Portuguese in the seventh century [15].

Pepper is the leading vegetable and spice crop grown in Ethiopia [19]. The central (eastern and southern Showa), western, north western (Wollega and Gojjam) and the southern part of the country are the potential pepper producing areas. Chilli pepper is an important agricultural crop, not only because of its economic importance, but also due to the nutritional and medicinal value of its fruit. The fruit is an excellent source of natural colors and antioxidant compounds whose intake is an important health protecting factor by prevention of widespread human diseases [16]. Pepper fruit is consumed as a fresh vegetable or dehydrated for use as a spice after changing to powder. The antioxidant vitamin A, C and E are present in high concentrations [20].

Peppers are a warm season crops that do best with a long, frost-free season to produce good quality and high yields [6]. It has been cultivated in many parts of the country because the powdered Chilli pepper is a major part of spice used to prepare the traditional sauce called '*wot*'. 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 [5].

The decline of Chilli pepper production is also attributed to poor varieties, poor cultural practices, the prevalence of fungal and bacterial as well as viral diseases [11]. Even though Chilli 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 confront-

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ed with various production and marketing related problems. In spite of its importance, the pepper production system for green and dry pods has remained low input and low output, with a national average yield of 49.51 qt/ha for green pepper and 15.81 qt/ha for red pepper, respectively [7]. This yield loss might be due lack of improve variety, sowing methods, use of appropriate plant spacing and environmental conditions [28]. The decline of Chilli pepper production is also attributed to a lack of improved varieties, poor cultural practices, the prevalence of fungal (blights) and bacterial wilt, as well as viral diseases [11].

There has also been no research on the evaluation of small-pod Chilli peppers, which enables the growers to select the best-performing varieties in the study area. Evaluation of selected varieties are 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 Chilli pepper growers and processors. Furthermore, the increasing demand for small pod Chilli peppers to feed the growing human population and supply the ever-expanding pepper industries at the national and international level has created a need for the expansion of pepper cultivation in areas where it has not ever been extensively grown [5]. Superior genetic material is obtained through plant breeding activities [21]. So, better adaptable and well-performing varieties with improved cultural practices could be a possibility to boost the quality and marketable production of the crop, so that the farmers would benefit from cultivating those adaptable and improved varieties in the study area. Therefore, this research was conducted with the following objective:

- To evaluate, select and recommend the best performing, high yielding, and stable small-pod Chilli pepper variety (ies) for the study area.

Materials and Methods

Description of the Experimental Site

The experiment was conducted in the midland (Adola district) areas of Guji Zone at one location during 2021 and 2022 cropping season. Adola district is located at about 470 to the south from Addis Ababa. Adola district is characterized by three agro-climatic zones, namely Dega (high land), Weina-dega (mid land) and Kola (low land) with different coverage. The mean annual rain falls and temperature of the district is about 900mm and 12-34 ^{0}c respectively. Based on this condition two-time cropping season was commonly practiced i.e. Arfasa (main cropping season) which start from March to April especially for maize, haricot bean, sweet potato and Irish potato. The second cropping season is called Gena (short cropping season) which was practiced as double cropping using small size cereal crops like tef, potato, Pepper, and barley after harvesting the main cropping season crops. This study was also conducted during short cropping season in midland areas of Guji zone.

Treatments and Experimental design

About 5 newly released improved small pod Chilli Pepper varieties (Kume, Dame, Dinsire, Melka Oli and Melka Dera) were brought from Bako and Melekasa Agricultural Research Center and evaluate along local check. The trial was carried out in Randomized Block Design (RCBD) having three replications in a gross plot size of 2.1m×2.8m (5.88 m^2) with a spacing of 1.40 m between blocks and 60 cm between plots. After 55 days of sowing or 3-4 true leaf stages uniform grown, healthy and vigorous seedlings was transplanted to the experimental field and planted at a spacing of 40 cm between rows and 20 cm between plants. Urea at 100 kg $ha^{-1}$and NPS at 200 kg $ha^{-1}$was applied to each treatment where NPS was applied during planting while 50% of urea during planting and the remained 50% urea was applied after one and half month. All appropriate agronomic practices such as weeding, watering and hoeing were conducted uniformly both at the nursery and experimental field.

Land Preparation and Raising Seedlings in the Nursery

The field for nursery bed was ploughed and harrowed to bring it to a fine tilth and a seed bed with a size of 3 m in length and 1 m in width was prepared. Seeds are drilled by hand in to the Nursery beds of 1 m width and 3 m length at the inter-row spacing of 15 cm. In the nursery 10 kg NPS ha^{-1} in the form of NPS (19% N, 38% $P_2O_5$and 7% S) were applied at sowing. After sowing, the beds were covered with dry grass mulch until emergence and watered using a watering can. A week before transplanting, water supply to the nursery seed bed was reduced in order to harden the seedlings to reduce transplanting shock. Before transplanting, the seedlings were watered to enhance easy uprooting and to prevent root damage.

Transplanting Seedlings

Uniform, healthy and vigorous seedlings (standard seedlings) having a height of 20-25 cm [9] was transplanted (after about 6 to 7 weeks in the nursery) in to the experimental field on beds at the specified spacing in the designated plots. The Seedlings were planted at the spaced of 30 cm between plants and 70 cm between rows. 200 kg/ha NPS 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 [9]. There were five rows per plot and 7 plants per row with a total of 35 plants per plot.

Data Collected

The data were collected on plots of the middle rows, leaving aside plants in the border rows as well as those at both ends of each row. The parameters were measured are: Days to 50% flowering, Days to pod development, Days to pod maturity, Plant height (cm), Pod length (cm), Number of branches per plant, Pod diameter (cm), Number of pod per plant, Marketable yield (qt/ha), Unmarketable (qt/ha) were collected and analyzed.

Table 1: Small pod Chilli Pepper varieties and local check were tested.

Variety	Year of Release	Maintainer and Seed source	Adaptation (masl)	Rainfall (mm)
Kume	2015	BARC	1200-1800	700-1000
Dame	2015	BARC	1200-1800	700-1000
Dinsire	2015	BARC	1200-1800	700-1000
Melka dera	-	MARC	1200-2200	900-1200
Melka oli	-	MARC	1200-2200	-
Local	-	-	-	-

Source: - (MoARD, 2009)

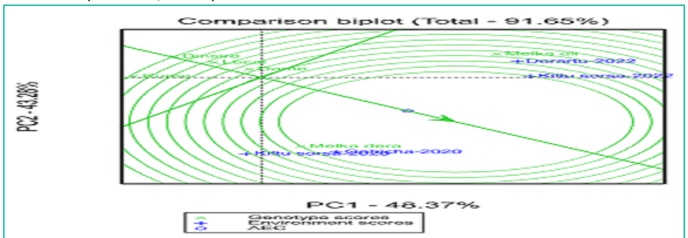

Figure 1: GGE biplot stability analysis for marketable green pod yield small-pod Chilli pepper.

Table 2: Mean squares of ANOVA Phenology, growth, yield and yield traits of for small-pod Chilli pepper varieties in 2020 and 2022cropping season at Adola district.

Character/Traits	Source of Varaition						
	Rep.	Var.	Loc.	Yr	Var *Loc	Var *Yr	Var *Loc*Yr
DF	19.18Ns	30.82Ns	2723.35***	527.22***	31.73Ns	49.78Ns	6.01Ns
DPD	16.22Ns	8.36Ns	379.19***	1494.22***	22.74*	20.26Ns	3.27Ns
DM	22.16Ns	209.3***	1494.25***	14280.5***	51.85**	60.5**	16.94**
PH (cm)	499.99*	707.96*	182.29Ns	2612.68*	119.33Ns	44.47Ns	12.89Ns
NBPP	1.61Ns	1.72*	4.13*	64.17***	0.83Ns	1.45Ns	0.84Ns
PL (cm)	1.42Ns	14.83***	5.22**	12.84***	1.23*	2.13*	0.73**
PD (cm)	0.05Ns	0.11*	0.15*	0.64***	0.05Ns	0.02Ns	0.19Ns
NPPP	2768.41*	906.56Ns	21431.95***	70875***	807.48**	1717.4Ns	25.65*
MGPyldqt/ha	3135.1*	1982.82*	12950.73***	16385.33***	435.73**	1796.82*	20.16**
MRPyldqt/ha	69.19Ns	165.83*	333.27***	1114.47***	44.06*	38.2Ns	5.41*
Unmyld qt/ha	0.21Ns	14.94***	31.59***	16.29*	5.35*	5.84*	1.35Ns

Signifcant'***' 0.001, '**' 0.01, '*' 0.05 and Non Significant (NS) at P>0.05, DF= Days to 50% flowering, DPD= Days to 50% pod development, DM= Days to 90% pod maturity, PH= Plant Height(cm), NBPP= Number of Brach per plant, PL(cm)= Pod length(cm), PD(cm)= Pod Diameter(cm), NPPP= Number of pod per plant, MGPyldqt/ha Marketable green pod yield qt/ha, MRPyldqt/ha= Marketable red dry pod yield qt/ha, and Unmarketable pod yield qt/ha.

Data Analysis

Field data were analyzed by using SAS software for the data following the standard procedures outlined by Gomez and Gomez (1984). Comparisons among the treatment means were done using Fisher's protected Least Significant Difference (LSD) test at 5% level of significant.

Results and Discussion

The overall locations, analysis of variance showed that statistically significant differences (*P*<0.05) were observed among the interaction of varieties and locations for days to 50% pod development, days to 90% physiological maturity, pod length, number of pod per plant, marketable green pod yield, marketable red dry pod yield and unmarketable yield. However, non-significant difference at (*P*>0.05) was observed among their interaction of locations to varieties for days to 50% flowering, 50% days of pod development, plant height, number of branch per plant and pod diameter (Table 2). Moreover, over all locations, analysis of variance showed statistically significant differences (*P*<0.05) were observed among the interaction of varieties, locations and years for days to 90% maturity, pod length, number of pod per plant marketable green pod yield, and marketable red dry pod yield. However, non-significant difference at (*P*>0.05) was observed among their interaction of locations, varieties, years for days to 50% flowering, plant height, pod diameter and unmarketable pod yield (Table 2).

Phenology

The mean values for five improved Chilli pepper varieties and one local check variety are shown (Table 3). The variation with respect to flowering, pod development and maturit- from 45.5 to 50.17, 65.75 to 67.83, and 149.5 to 162 days respectively. As over all location mean value indicate that the longest days to 50% flowering, Pod development, and Maturity were recorded from Melka dera, Dame and Local check Chilli pepper varieties (50.17, 67.83 and 162 days) respectively. The results indicate that, the traits are affected by both genotype and environment. 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. This result was in agreement with the finding of Seleshi *et al*. (2014) who reported that days to flowering of hot pepper varieties was significantly affected by the interaction effect of variety and location. Geleta (1998) also reported 74 to 97 days and 114 to 158 days for flowering and maturity, respectively, of 18 Capsicum genotypes grown at Melkasa Research Center.

Table 3: The overall locations and years mean values of Phenology traits of Chilli pepper varieties in 2020 and 2022 cropping season.

Varieties	Phenology Parameters		
	Days to 50% flowering	Days to 50% pod development	Days to 90% maturity
Melka Oli	48.42	66.67	158b
Melka Dera	50.17	67	155bc
Dame	47.33	67.83	155bc
Dinsire	46.67	66	149.5d
Kume	47.08	65.75	154c
Local Check	45.5	67.58	162a
Mean	47.52	66.81	155.58
LSD (0.05)	4.94	2.68	3.38
CV (%)	12.64	4.89	2.65

Growth Parameters

The mean values of five (5) improved varieties and one local check of Chilli pepper are shown (Table 4). The variations with respect to plant height, number of branches, and pod length were ranged from 40.54 to 60.39, 2.66 to 3.62, and 3.14 to 6.24 observed respectively. As overall location mean value indicates that the highest plant height, number of branch, and pod length were recorded from Melka dera Chilli pepper varieties (60.39cm, 3.62 and 6.24cm) respectively whereas among the tested varieties whereas kume, Dame and kume were recorded the lowest plant height, number of branch and pod length (40.54cm, 2.66 and 3.14cm) respectively. The significant difference in fruit length among the hot pepper varieties is attributed to their in-

Table 4: The overall locations and years mean values of Growth traits of Chilli pepper varieties in 2020 and 2022 cropping season.

Varieties	Growth Parameters		
	Plant height (cm)	Number of branch	Pod length (cm)
Melka Oli	53.72abc	3.49a	4.33b
Melka Dera	60.39a	3.62a	6.24a
Dame	44.3cd	2.66b	3.65c
Dinsire	48.88bcd	3.08ab	3.45c
Kume	40.54d	2.95ab	3.14cd
Local Check	57.39a	3.49a	4.35c
Mean	50.87	3.21	4.19
LSD (0.05)	10.59	0.69	0.6
CV (%)	25.33	26.14	17.43

herited traits and adaptability to the environmental condition of the study area. Gupta et al. (2022) stated that the character of plant height can also be used to predict Chilli productivity. The higher total fruit per plant, the higher the productivity and can be shown in Chilli plants that have high plant height.

Yield components

The overall location mean values revealed that the highest pod diameter and number pod per plant were recorded from Dame (1.24cm), and Melka oli (80.88) Chilli pepper varieties respectively whereas the lowest pod diameter and number pod per plant from melka oli (0.97cm), and Melka dera (54.72) Chilli pepper varieties were recorded respectively (Table 5). In line with this result, Amare *et al*. (2013) found different fruit number per plant due to variety differences. The results of this study are also consistent with that of [22] who reported that Chilli fruit weight was strongly influenced by fruit length and fruit diameter.

Yield

The overall location mean values revealed that the highest Marketable green pod yield, Marketable red dry pod yield and Unmarketable dry pod yield were recorded from Melka oli (96.34 qt/ha), Melka oli (23.16 qt/ha) and Local check (3.44 qt/ha) Chilli pepper varieties respectively whereas the lowest Marketable green pod yield, Marketable red dry pod yield and Unmarketable dry pod yield from Kume (66.86qt/ha), Local check (12.72 qt/ha) and melka dera (0.39qt/ha) Chilli pepper varieties respectively. In other cases, the highest Marketable green pod yield and Marketable red dry pod yield were obtained from Melka oli variety (96.34 & 23.16 qtha-1) and followed by Melka dera variety (92.89 and 19.32 qtha1) respectively whereas the lowest Marketable green pod yield and Marketable red dry pod yield Kume (66.86 qt/ha), and Local check (12.72 qt/ha) were recorded respectively (Table 5).

The yield might be more influenced by traits such as pod number per plant, and pod diameter. The variation of marketable yield of these varieties could be due to difference in genetic characteristics and agro ecological adaptability nature [11]. The differential response by different varieties may be due to differences in genetic constituents of the varieties and variable environmental condition [3]. The results of this study are also consistent with that of [21] who reported that the number of fruits planted has an effect on the weight of the resulting crops. The results of this study is also in agree with that of in agreement with that [27] who reported Chilli pepper productivity was influenced by fruit weight and fruit number per plant. Furthermore, the main factors that greatly affect Chilli productivity are the genetic material used [18] and the environment in which Chilli is grown [17].

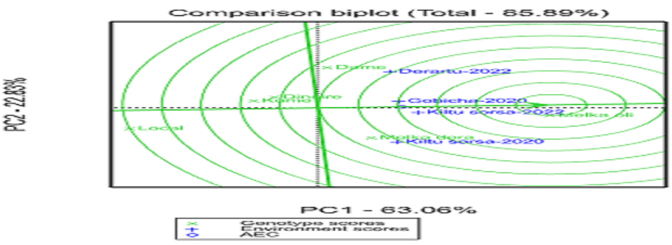

Figure 2: GGE biplot stability analysis for marketable red dry pod yield small-pod Chilli pepper.

Figure 3: The performance of Chilli pepper exp't at Kiltu sorsa on-farm.

GGE Biplot Stability Analysis

The GGE biplot stability analysis showed that PC1 and PC2 explained 48.37% and 43.28% of the GGE variance, respectively (Figure 1). Figure 1 helps visualize the marketable green pod yield performance and stability of small-pod Chilli peppers. As a result, the biplot showed that variety melka dera was in the first concentric circle, closer to horizontal line, followed by melka oli away from the mean vertical line, which indicates this variety was stable and a high yielder among the varieties. The environments as well as genotypes that fall in the central (concentric) circle are considered as an ideal environments and stable genotypes [25]. Varieties proximal to the arrow at the center of the concentric circles (ideal varieties) are assumed to be suitable.

The GGE biplot analysis showed that PCA1 contributed 64.06% and additionally PCA2 was explained 22.83% of the total variance, respectively (Figures 2). The method developed for genotype-by-environment data analysis is GGE biplot analysis [26]. In a genotype-focusing scaled comparison of GGE biplots, a variety located nearest to the central concentric circles is both highly marketable and most stable. Figure 2 describes that the varieties melka oli and melka dera, which fell in the first concentric circle, were the ideal varieties in terms of the highest marketable red dry pod yield performance. While variety melka oli was located closer to the ideal variety, it became more stable and desirable.

Table 5: The overall locations and years mean values of yield and yield component of Chilli pepper varieties in 2020 and 2022 cropping season.

Varieties	Yield and Yield components				
	Pod diameter(cm)	No. of pod per plant	Marketable green pod yield(qt/ha)	Marketable red dry pod yield(qt/ha)	Un Marketable Dried pod yield(qt/ha)
Melka Oli	0.97b	80.88a	96.34a	23..16a	0.97cd
Melka Dera	1.19a	54.72b	92.89ab	19.32ab	0.39d
Dame	1.24a	64.46ab	76.34bc	16.32bc	2.34bc
Dinsire	1.19a	71.55ab	67.54c	15.72bc	1.05cd
Kume	1.17a	73.74ab	66.86c	15.44bc	2.044bc
Local Check	1.18a	68.88ab	72.11c	12.72c	3.44a
Mean	1.16	68.92	78.68	17.16	19.06
LSD (0.05)	0.15	21.08	16.57	4.45	1.11
CV (%)	16.03	37.21	25.62	31.54	1.71

Conclusions and Recommendation

Pepper is one of the most important spice and cash crop produced in Ethiopia. Availability of improved varieties is among the best technologies to improve Chilli productivity. The yield of the crop is affected by the Agronomic practices, lack of improved varieties, insect pests, and the growing environmental conditions existing in Guji zone. An adaptation trial is one of the most important mechanisms to select best varieties for the farmers easily. The overall locations, analysis of variance showed statistically significant differences (P<0.05) were observed among the interaction of varieties, locations and years for days to 90% maturity, pod length, number of pod per plant marketable green pod yield, and marketable red dry pod yield. However, non-significant difference at (P>0.05) was observed among their interaction of locations, varieties, years for days to 50% flowering, plant height, pod diameter and unmarketable pod yield (Table 2). The highest marketable dry red and dry pod yields were recorded from Melka Oli (23.16 qt/ha), followed by Melka Dera (19.32 qt/ha), respectively. But the lowest marketable dry red pod yield (12.72 qt/ha) was obtained from a local check Chilli pepper variety. Therefore, two improved small pod Chilli pepper varieties, i.e., Melka oli and Melka dera, are stable, high yielder, selected and recommended for midland areas of the Guji zone.

Author Statements

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