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Research Article

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Yield performance evaluation of kabuli and desi chickpea (*Cicer arietinum* L.) varieties under rainfed condition

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ABSTRACT

Chickpea is one of Ethiopia's main grain legume crops and it is third most important export legumes after faba bean and haricot bean. The performance information for chickpea cultivars under varying environmental conditions in the Somali region is limited. A field experiment was conducted to test the adaptability of 14 released chickpea varieties (both kabuli and desi types) at Kebribeya and Jigjiga in 2021. The experiment was carried out using a complete randomized block design with three replications for both types separately. The analysis of variance computed for seven traits for each location and over the location revealed the presence of significant variability between varieties. Variety by location interaction was highly significant for most yield and yield related for both types, this indicated that location-specific variety selection is needed. Hence, among the tested kabuli types, Koka and Hora for Kebribeya and Ejera and Koka for Jigjiga were selected based on their grain yield potential and other yield and yield-related traits. Regarding the desi-type Dalota and Dimtu for Kebribeya and Dalota, Natoil and Teketay for the Jigjiga location were the best high-yielder varieties among tested varieties. Additionally, the phenotypic correlation between traits revealed that most traits were associated with grain yield. Specifically, days to maturity and the number of pods per plant were highly correlated with grain yield in both types and were also used as important traits for variety selection. Therefore, the selected varieties from both chickpea types are recommended for popularization in study areas and other similar agroecology.

KEYWORDS: Adaptation, Chickpea, Correlation, Evaluation, Pulse, Varieties

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INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a widely cultivated pulse crop that belongs to the family Fabaceae. Chickpea is a nutritious and versatile food source for millions of people around the world. It is rich in protein, carbohydrates, fiber, oil, calcium, and phosphorus (Jukanti *et al.*, 2013). It has 2n=16 chromosomes and a haploid genome size of 738 Mb (Varshney *et al.*, 2013). Chickpea originated from southeastern Turkey (Ladizinsky, 1975) and has two main types: desi and kabuli. Desi chickpeas have small dark seeds with a rough surface and purple or pink flowers, while kabuli chickpeas have large beige seeds with a smooth surface and white flowers (Upadhyaya *et al.*, 2008).

Ethiopia is one of the main chickpea producers in the world and ranked sixth in 2016 (FAOSTAT, 2019). Chickpea is an important crop in Ethiopia for food security and income generation (Fikre & Bekele, 2020). It is grown in the central, northern and eastern highland areas of the country at an altitude of 1400-2300 m.a.s.l and annual rainfall between 500 and 2000 mm (Anbessa & Bejiga, 2002). The crop thrives well in vertisols and clay soils (Bekele *et al.*, 2021). The production and area of chickpeas have increased significantly from 60,085 tons and 109,750 hectares in 1993 to 473,570 tons and hectares in 2017, respectively (CSA, 2017).

The Somali region is one of the potential areas for chickpea production in Ethiopia, but there is limited information on the performance of different chickpea cultivars under varying environmental conditions in the region. Whereas, some high-yielding, disease resistant, erect, early maturing, and widely adaptable chickpea varieties have been developed in the country. Due to the high genotype-environment interaction, chickpea varieties respond to differences in various locations (Shumi *et al.*, 2018; Dawane *et al.*, 2020). Therefore, this experiment was conducted to evaluate recently released kabuli and desi chickpea varieties under rainfed conditions and to identify the best performing varieties for the Fafen zone in the Somali region of Ethiopia.

MATERIAL AND METHOD

Study Location

The experiment was carried out in the Jigjiga and Kebribeya districts, Fafen zone of the Somali Region, Ethiopia. Jigjiga has an altitude of 1656 meters above sea level, a latitude of 9° 21' north, and a longitude of 42° 48' east. It has a mean annual rainfall of 404 mm and average maximum and minimum monthly temperatures of 26 °C and 12 °C, respectively. Kebribeya is located at an altitude of 1410 meters above sea level, a latitude of 9° 27′ N and a longitude of 42° 59′ E. The mean minimum and maximum temperatures in the areas are 17 and 32 °C, respectively (Climate-Data.org, 2023). The main crops grown in the districts are sorghum, maize, wheat, barley, and beans. Farmers grow chickpeas in the late season after the main crop is harvested.

Treatment, Design, and Field Management

Fortin recently released varieties (seven Kabuli and Desi types) and local check varieties were tested in the study locations. The seeds for the aforementioned chickpea varieties were acquired from the Debrazayit Agriculture Research Center, Ethiopia. The experiment was designed using a Randomized Completely Block Design (RCBD) with three replications, separately, for both types. The gross plot size was 4 m x 1.6 m, having four rows, two middle rows were used for data collection. The spacing between rows and plants was used at 40 cm and 10 cm, respectively. 60 kg NPS ha^{-1} fertilizer was applied at the time of planting. All other agronomic practices were applied uniformly according to the recommendation for chickpeas. The aforementioned treatments, experimental design, and field management were used for both study locations.

Data Collection

Morphological and physiological data were collected from central rows. For data recorded on a single plant base, ten plants were randomly taken and tagged from the net harvested plot, and the mean value was used for statistical analysis; it included: plant height (starting from the base of the ground to the tip of the plant); number of pods per plant (the number of total pods in ten randomly taken plants from the central rows was counted at physiological maturity and the means were recorded as the number of pods per plant); number of seeds per pod (the number of total seeds from the above pods was counted and then the total number of seeds was divided by the total number of pods to get the average number of seeds per pod).

Data were recorded on plot bases including: days to flowering (days from planting up to the time when 50% of plants have flowered), days to maturity (days from planting up to the time when 95 % of plants showed a yellow color), grain yield (plants harvested from the central rows and was threshed to determine grain yield (g)), 100 seed weight (weight of 100 seeds in gram drawn randomly from the bulk seeds of each plot).

Data Analysis

The data of the yield and yield components were collected from the field and subjected to individual and combined analysis of variance using an appropriate statistical analysis system (SAS Institute, 2020). The F test will be carried out to combine the analysis and significant differences between mean values were compared using the least significant test (LSD) at $P<0.05$. A simple correlation was performed for seven traits to determine the association between the traits.

RESULT AND DISCUSSION

Analysis of Variance

The variance analysis was conducted for each chickpea type (kabuli and desi) separately per location and to check the presence of significant differences between the varieties (Table 1). The varieties exhibited a significant difference at $P<0.05$ for plant height, pods per plant, seed per pod, 100 seed weight, and grain yield at both locations and types. Furthermore, the varieties showed a significant difference from day to flowering and day to maturity expected in Jigjiga for both types.

The combined analysis of variance over locations was performed for each type of chickpea and the result presented in Table 1 for

Table 1: Combined ANOVA of mean squares for different traits for Kabuli and Desi types of chickpeas

Types of chickpea	Source of variation	DF	DM	PH	PPP	SPP	HSW	GY
Kabuli								
	Varieties (Var)	45.103**	47.13ns	44.85**	557.9**	0.178**	133.901**	827414**
	Location (Loc)	205.92**	1826.88**	1821.61**	15280.0**	0.019ns	105.165**	2611850**
	Var x Loc	26.59*	25.21ns	57.72**	271.5**	0.078*	140.859**	232847**
	Mean	45.405	96.643	40.652	45.983	1.292	26.640	1916.1
	CV (%)	7.18	4.52	8.56	6.38	13.70	9.47	12.37
Desi								
	Varieties (Var)	29.91**	88.63**	65.43**	246.85**	0.17**	56.609**	877658**
	Location (Loc)	85.71**	298.66**	961.92**	936.25**	0.019**	8.326ns	1669007**
	Var x Loc	9.43ns	16.444ns	9.726ns	139.34**	0.078ns	2.179ns	326855**
	Mean	45.81	96.47	39.262	55.545	1.22	26.309	1598.4
	CV (%)	6.05	3.70	6.24	13.44	14.72	6.36	12.71

**=significant at $P<0.01$, DF=day to flowering, DM=days to maturity, PH=plant height, PPP=pods per plant, SPP=seed per pod, HSW=hundred seed weight, GY=grain yield, CV(%)=coefficient of variation by percent

seven traits with the main source of effects: variety (var) and location (loc) and interaction (var x loc). The mean square of the varieties had a significant difference ($P<0.05$) in both types for all traits. Similarly, location also had a significant difference except for seed per pod and hundred seed weight traits for the kabuli and desi types, respectively. On the other hand, the mean sequence of the var x loc interaction showed significant differences for all traits except days to maturity for the kabuli type, while it had only significant differences for the pod per plant and grain yield for the desi type (Table 1).

The presence of significant differences among chickpea varieties tested, location and interaction for phenological parameters, growth traits, yield and yield components were also reported by Alemu *et al.* (2017) and Shumi *et al.* (2018). The significant difference in the varieties provides a specific and broad selection and recommends the best variety.

The Mean Performance of Varieties

Analysis of variance results indicated the presence of significant variations between varieties, locations, and their interaction. Hence, the varieties had inconsistent performance across the test environments for the mentioned traits. Therefore, the highest and lowest mean performance of selected varieties of kabuli and desi types of chickpeas per location are presented in the following subsections to not overlook the variety performance per location.

Phenological and growth parameters

The mean performance of the varieties for seven traits per location is presented in Tables 2 and 3. The analysis of variance result indicates that the variety had a significant difference ($p<0.05$) for day-to-day flowering and day-to-maturity in Kebribeya but not in Jigjiga. Early flowering was observed from the Habru variety among kabuli types and Natoil, Teketay, and Local among desi types. However, a flowering delay was observed in the Arerti and Dalota varieties for the kabuli and desi types in the Kebribeya, respectively. Day-to-maturity is closely related with day-to-flowering traits in both chickpea types. The Habru and Natoil varieties were an early mature variety among kabuli and desi types in Kebribeya, respectively. The late maturity was recorded for the variety Arerti (kabuli) and Dalota, Dimtu, and Dz-10-11(desi).

The variety was also significantly different for the height of the plant for both locations (Table 1), the longest plant was observed from the Arerti and Koka (kabuli) and Teketay (desi) varieties for Kebribeya and Ejera (kabuli) and Teketay (desi) for Jigjiga. The mean of the shortest plant height was recorded from the Habru and Natoil variety for Kebribeya and Kobo (kabuli) and Geletu (desi) for Jigjiga.

Yield and yield related traits

The mean grain yield ranged from 1044 to 2877 kg ha^{-1} and 1094 to 2023 kg ha^{-1} for Kebribeya and Jigjiga, respectively (Tables 2 & 3). The highest grain yield was obtained from the Koka and Hora variety among kabuli and Dalota and Dimtu among desi types for Kebribey; and Ejera and Koka among kabuli and Dalota, Natoil, Teketay among desi types for Jigjiga. The lowest grain yield was recorded from the Dhera and Habru variety among kabuli and Dz-10-11 and local among desi types for Kebribey; Habru among kabuli and Dz-10-11 and local among desi types for Jigjiga (Tables 2 & 3).

The number of pods per plant ranged from 50 to 73 pods and 8 to 56 for Kebribeya and Jigjiga, respectively. The maximum and minimum number of pods per plant was counted from varieties

Table 2: Mean comparison of kabuli and desi types of chickpea varieties for different traits at Kebribeya

Type	Entry No.	Variety name	DF	DM	PH	PPP	SPP	GY	HSW
Kabuli									
	1	Arerti	55.33a	111.67a	52.67a	64.33a-d	1.27b	2336.33b	20.40d
	2	Dhera	44.67d	102.67bc	44.67b	60.33d	1.27b	1551.83c	23.54bc
	3	Ejera	46.00cd	101.33c	46.00b	66.67abc	1.23b	1981.83b	23.08c
	4	Hora	50.00b	102.00bc	46.67b	68.00ab	1.53a	2768.00a	25.86b
	5	Habru	40.67e	96.67d	44.33b	62.07cd	1.23b	1561.00c	24.73bc
	6	Koka	48.00bc	105.67b	50.67a	70.00a	1.53a	2877.17a	28.93a
	7	Kobo	48.67bc	102.67bc	45.67b	64.00bcd	1.13b	2082.00b	28.87a
	Mean		47.62	103.24	47.24	65.06	1.31	2165.45	25.06
	LSD		3.14	3.95	3.01	5.82	0.26	407.87	2.47
Desi									
	9	Dalota	52.67a	104.67a	46.67ab	73.40a	1.40ab	2386.33a	27.64b
	10	Dimtu	48.67b	102.67a	45.00bc	73.20a	1.27abc	2465.50a	30.53a
	11	Dz-10-11	48.67b	103.33a	41.00e	58.40b	1.07c	1264.50c	24.33c
	12	Geletu	44.00c	96.00b	43.67cd	55.33b	1.27abc	1684.33b	29.17a
	13	Natoil	44.67c	93.33c	41.33e	50.33b	1.13bc	1380.67bc	25.56c
	14	Teketay	46.00c	96.67b	48.67a	60.07ab	1.47a	2359.00a	27.62b
	15	Local	46.00c	97.33b	42.00de	51.13b	1.00c	1044.17c	22.42d
	Mean		47.24	99.14	44.05	60.27	1.23	1797.79	26.75
	LSD		2.12	2.13	2.23	13.47	0.27	7.14	1.46

The mean values followed by similar letters in each column did not have significant differences from each other. LSD (5%)=least significant difference at $P<0.05$, DF=day to flowering, DM=days to maturity, PH=plant height (cm), PPP=pods per plant, SPP=speed per pod, GY=grain Yield (kg ha^{-1}), HSW=hundred seed weight (gm)

Table 3: Mean comparison of kabuli and desi types of chickpea varieties for different characteristics in Jigjiga

Type	Entry No.	Variety name	DF	DM	PH	PPP	SPP	GY	HSW
Kabuli									
	1	Arerti	45.67	93.00	29.33cd	30.60c	1.23bc	1691.02ab	18.88d
	2	Dhera	43.33	90.67	34.80bcd	14.07d	1.10c	1466.52bc	27.67c
	3	Ejera	40.67	88.67	42.20a	41.27b	1.53ab	1974.60a	40.11a
	4	Hora	41.33	88.00	36.67ab	29.53c	1.67a	1694.71ab	32.46bc
	5	Habru	43.33	91.33	30.80bcd	8.93e	1.27bc	1263.44c	30.12bc
	6	Koka	44.00	90.00	36.33abc	52.03a	1.13c	2023.59a	34.35ab
	7	Kobo	44.00	88.67	28.33d	13.93d	1.07c	1553.06bc	13.97d
	Mean		43.19	90.05	34.07	26.91	1.27	1666.71	28.22
	LSD		7.87ns	10.16ns	7.17	4.89	0.37	403.64	5.99
Desi									
	9	Dalota	47.33	102.00	38.40ab	58.87a	1.33abc	1738.09a	27.64b
	10	Dimtu	43.33	93.33	33.80bc	52.20ab	1.40ab	1427.81b	31.84a
	11	Dz-10-11	45.33	93.33	32.60c	40.57c	1.07c	1307.75bc	22.82cd
	12	Geletu	45.00	94.00	29.47c	47.20bc	1.10bc	1236.35bc	26.91b
	13	Natoil	42.67	90.00	34.20bc	56.87ab	1.20abc	1472.62ab	24.40bcd
	14	Teketay	41.33	90.00	41.33a	50.00abc	1.47a	1516.67ab	25.86bc
	15	Local	45.67	94.00	31.53c	50.07abc	1.03c	1094.40c	21.58d
	Mean		44.38	93.81	34.48	50.82	1.23	1399.10	25.86
	LSD		6.76ns	7.82ns	5.79	10.50	0.30	282.80	3.99

The mean values followed by similar letters in each column did not have significant differences from each other. LSD (5%)=least significant difference at P<0.05, DF=day to flowering, DM=days to maturity, PH=plant height (cm), PPP=pods per plant, SPP=seed per pod, GY=grain yield (kg ha^{-1}), HSW=Hundred seed weight (gm)

that had the highest and lowest grain yield recorded in both the location and the chickpea type. This result indicated that the number of pods per plant could serve as an important selection criterion for the high-grain yield variety.

Significant variations were also observed for the number of seeds per pod. The maximum and minimum number of seeds per pod were recorded from varieties Hora (1.67) and Local (1) for both locations, respectively. The weights of the hundred seeds ranged from 13 to 40 g. The maximum of 100 seed weights was recorded from the Koka and Kobo varieties among kabuli and Geletu and Dimtu among desi types for Kebribey; Ejera among kabuli and Dimtu among desi types for Jigjiga (Tables 2 & 3).

Mean Performance of Varieties over Locations

The mean performance of the varieties in locations for seven traits for both kabuli and desi types (Table 4). From the kabuli type, the highest grain yield was recorded from the Koka variety Koka (2450.38 kg ha^{-1}) and followed by variety Hora (2231.36 kg ha^{-1}). The Dhera and Habru varieties had the lowest grain yield. The Koka variety had an intermediate maturity period (97.83 days) with a high number of pods per plant (61.02 pods) and 100 seed weight (31.64 g). The second highest grain yielder variety (Hora) was the first for days to maturity (95 days) and had a large number of seeds per pod (1.60 seeds).

Regarding the desi type, Dalota has the highest grain yield (2062.21 kg ha^{-1}) followed by Dimtu (1946.65 kg ha^{-1}), and Teketay (1937.83 kg ha^{-1}). In contrast, the lowest grain yield was obtained from the local and was followed by Dz-10-11. Dalota was late for days to flowering (50 days) and days to maturity (103.33 days, with the highest number of pods per plant (66.13 pods). The other high yielding variety (Dimtu) was intermediate for days to maturity (98 days) and hundred seed weights (Table 4). Therefore, Koka and Hora varieties among Kalbi, Dalota, and Dimtu types among desi types were selected for their higher yield performance and other yield-related traits for both locations. Shumi *et al.* (2018) and Funga *et al.* (2017) performed chickpea adaptation across locations and reported the varieties Dalota and Dimtu as high yielders, respectively.

Correlation between Traits

The result of the phenotypic correlation as shown in Table 5 type of kabuli (lower diagonal), the grain yield was highly positively correlated (P<0.01) with the days of flowering (r=0.48), the days of maturity (r=0.52), the height of the plant (r=0.69) and the number of pods per plant (r=0.66). The number of pods per plant was also positively correlated with the days of flowering, the days of maturity, and the height of the plant. A positive and significant association was observed between 100 seed weight and the number of seeds per pod, as well as the days from flowering with the days to maturity and the height of the plant (Table 5).

Regarding the type of desi, Table 5 (upper diagonal) showed that the grain yield had a positive and significant (P<0.01) association with all other traits. The number of seeds per pod was positively correlated with the height of the plant and the number of pods per plant. Significant and positive correlations were also observed between days of flowering, days of maturity, plant height, and the number of pods per plant. However, the weight of 100 seeds was not significantly correlated with grain yield in the types of kabuli chickpeas (Table 5).

Generally, days of flowering, days of maturity, plant height, and number of pods per plant were correlated with grain yield in both types. A similar result was reported by Dawane *et al.* (2020). The result of a non-significant correlation of 100 seed weight with

Table 4: Mean comparison of kabuli and desi types of chickpea varieties for different traits combined over two locations

Type	Entry No.	Variety name	DF	DM	PH	PPP	SPP	GY	HSW
Kabuli									
	1	Arerti	50.50a	102.33a	41.00a-d	47.47c	1.25bc	2013.68bc	19.64d
	2	Dhera	44.00bc	96.67b	39.73bcd	37.20de	1.18bc	1509.18d	25.60c
	3	Ejera	43.33bc	95.00b	44.10a	53.97b	1.38b	1978.22bc	31.60a
	4	Hora	45.67bc	95.00b	41.67abc	48.77c	1.60a	2231.36ab	29.16ab
	5	Habru	42.00c	94.00b	37.57cd	34.50e	1.25bc	1412.22d	27.42bc
	6	Koka	46.00b	97.83ab	43.50ab	61.02a	1.33b	2450.38a	31.64a
	7	Kobo	46.33b	95.67b	37.00d	38.97d	1.05c	1817.53c	21.42d
	Mean		45.40	96.64	40.65	45.98	1.29	1916.08	26.64
	LSD		3.86	5.18	4.13	3.48	0.21	281.24	2.99
Desi									
	9	Dalota	50.00a	103.33a	42.53a	66.13a	1.37	2062.21a	27.64b
	10	Dimtu	46.00bc	98.00b	39.40b	62.70ab	1.33	1946.65a	31.19a
	11	Dz-10-11	47.00ab	98.33b	36.80b	49.48c	1.07	1286.12bc	23.57de
	12	Geletu	44.50bc	95.00bc	36.57b	51.27c	1.18	1460.34b	28.04b
	13	Natoil	43.67c	91.67c	37.77b	53.60c	1.17	1426.64b	24.98cd
	14	Teketay	43.67c	93.33c	45.00a	55.03bc	1.47	1937.83a	26.74bc
	15	Local	45.83bc	95.67bc	36.77b	50.60c	1.02	1069.28c	22.00e
	Mean		45.81	96.48	39.26	55.55	1.23	1598.44	26.31
	LSD		3.28	4.23	2.90	8.86	0.21	128.87	1.98

The mean values followed by similar letters in each column did not have significant differences from each other. LSD (5%)=least significant difference at P<0.05, DF=days to flowering, DM=days to maturity, PH=plant height (cm), PPP=pods per plant, SPP=seed per pod, GY=grain yield (kg ha^{-1}), HSW=Hundred seeds weight (gm)

Table 5: Estimation of the correlation coefficient of seven traits of 14 varieties of kabuli chickpeas (lower diagonal) and desi type (upper diagonal) combined in the environment

	DF	DM	PH	PPP	SPP	HSW	GY
DF		0.86**	0.34*	0.35*	-0.08	0.09	0.39**
DM	0.81**		0.47**	0.47**	0.02	0.19	0.42**
PH	0.43*	0.74		0.55**	0.36*	0.25	0.63**
PPP	0.41**	0.69**	0.84**		0.38*	0.34*	0.69**
SPP	-0.10	0.04	0.28	0.19		0.52**	0.60**
HSW	-0.32*	-0.25	0.11	0.02	0.43**		0.55*
GY	0.48**	0.52**	0.69**	0.66**	0.37*	0.12	

Mean values followed by similar letters in each column did not have significant differences from each other. LSD (5%)=least significant difference at P<0.05, DF=day to flowering, DM=days to maturity, PH=plant height, PPP=pods per plant, SPP=seed per pod, HSW=hundreds of seeds weight, GY=grain yield

grain yield of kabuli type was also reported by Fikre and Bekele (2020) and Darkwa *et al.* (2016) in common beans. Therefore, any pair of traits that had a positive correlation with the present kabuli and desi chickpea varieties indicated the possibility of a correlated response to selection.

CONCLUSIONS

Fourteen chickpea varieties were tested to select the best-adapted variety in the Kebribeya and Jigjiga districts. There is a significant difference among the varieties tested across locations; this result indicated the different performance of the varieties with respect to location. The Koka and Hora varieties for Kebribeya and Ejera and Koka for Jigjiga were selected based on their potential for grain yield and other traits related to yield and yield among the types of kabuli tested. Regarding desi-type Dalota and Dimtu for Kebribeya and Dalota, Natoil and Teketay for the Jigjiga location, they were high-scoring yielder varieties. This study also revealed a positive and highest significant correlation between days to maturity and the number of pods per plant with grain yield. These varieties are selected based on their potential grain yields and other associated positive traits. Therefore, the result suggested the selected varieties for demonstration and popularization in the study areas and other similar agroecological areas.

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