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Research Article

Performance Evaluation of Kabuli Chickpea (*Cicer arietinum* L.) Varieties at Buno Bedele Zone, South-western Oromia

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Abstract

Chickpea (Cicer arietinum L.) is one of the most important pulse crops grown in the highland areas of Ethiopia, serving as a major source of food, income, and soil fertility improvement. However, its productivity remains low due to limited adoption of high-yielding and well-adapted varieties. Information on the performance of Kabuli chickpea varieties under the agro ecological conditions of the Buno Bedele Zone is limited. Therefore, a field experiment was conducted under rain-fed conditions at Chora and Gechi districts of the Buno Bedele Zone, southwestern Oromia, Ethiopia, during the 2023 and 2024 main cropping seasons. The objective of the study was to identify adaptable, stable, high-yielding, and disease- and insect-tolerant Kabuli chickpea varieties for the study area. Six improved Kabuli chickpea varieties (Ejeri, Asnake, Dhera, Koka, Habru, and Hora) were evaluated using a Randomized Complete Block Design (RCBD) with three replications. Data were collected on days to flowering, days to maturity, plant height, number of pods per plant, number of seeds per pod, hundred-seed weight, and grain yield, and analyzed using R statistical software. The analysis revealed significant ($P < 0.05$) differences among varieties for days to flowering, days to maturity, number of pods per plant, number of seeds per pod, hundred-seed weight, and grain yield, whereas plant height was not significantly affected. The highest grain yield was obtained from Koka (1568.04 kg ha^{-1}), followed by Habru (1271.81 kg ha^{-1}), while Hora produced the lowest grain yield (865.83 kg ha^{-1}). Based on grain yield performance and adaptability across environments, Koka and Habru were identified as the most promising varieties and are recommended for cultivation in the study area and similar agroecologies, with further promotion through demonstration and scaling-up activities.

Keywords

Adaptation, Cicer Arietinum, Grain Yield, Kabuli Chickpea, Southwestern Ethiopia, Varietal Evaluation

1. Introduction

Chickpea (*Cicer arietinum* L.) is one of the oldest cultivated grain legumes and an important pulse crop worldwide. It belongs to the family Fabaceae and is a self-pollinated, diploid species ($2n = 2x = 16$) with a relatively small genome size [15]. The crop has been cultivated for centuries across Africa, the Middle East, and South Asia, where it serves as a major source of dietary protein and essential nutrients [3]. Chickpea grains are widely consumed as dry seeds, green veg-

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etables, and processed food products, contributing significantly to food and nutritional security, particularly in developing countries where access to animal protein is limited.

Beyond its nutritional value, chickpea plays a vital role in sustainable agricultural systems. The crop is rich in protein, carbohydrates, vitamins, and minerals, making it an important component of cereal-based diets [11]. As a legume, chickpea forms a symbiotic association with nitrogen-fixing bacteria, thereby improving soil fertility and reducing the need for synthetic nitrogen fertilizers [6]. Consequently, it fits well into cereal-based cropping systems and crop rotation schemes, enhancing productivity and sustainability in rain-fed agriculture [12]. Furthermore, chickpea residues and straw provide valuable livestock feed, while the crop contributes to soil health and agricultural resilience, particularly in moisture-stressed environments [5].

In Ethiopia, chickpea is the most important pulse crop in terms of production and economic value. It is predominantly cultivated in the highland and mid-altitude regions, particularly on Vertisol and clay soils [7]. The crop serves as a source of food, income, export earnings, and livestock feed for smallholder farmers. According to the Central Statistical Agency [2], Kabuli chickpea occupies approximately 46,259.69 ha of land annually and produces about 899,327.88 quintals, with a national average productivity of 19.44 q ha^{-1}. Among the two major market classes of chickpea, namely Desi and Kabuli, farmers increasingly prefer Kabuli varieties because of their larger seed size, higher market value, and strong demand in both domestic and international markets [14]. As a result, the area devoted to Kabuli chickpea has expanded substantially over the past two decades and is expected to continue increasing in the future [1].

Despite the growing importance of chickpea in Ethiopia, its production remains limited in several potentially suitable areas, including the Buno Bedele Zone of southwestern Oromia [8]. Although the zone possesses favorable agroecological conditions, suitable soil characteristics, and increasing farmer interest, information on the adaptability and performance of improved Kabuli chickpea varieties under local conditions is lacking [4]. Evaluating improved varieties across diverse environments is essential for identifying cultivars with superior yield potential, adaptability, and stability. Therefore, this study was conducted to assess the performance of selected Kabuli chickpea varieties and identify the most suitable varieties for cultivation in the Buno Bedele Zone and similar agroecological areas of southwestern Ethiopia.

2. Materials and Methods

2.1. Description of the Study Areas

The experiment was conducted under rain-fed conditions during the 2023 and 2024 main cropping seasons in Chora and Gechi districts of the Buno Bedele Zone, southwestern Oromia, Ethiopia. The trials were established on farmers' fields to evaluate the performance and adaptability of improved Kabuli chickpea varieties under representative production environments.

2.1.1. Chora District

Chora District is located in the Buno Bedele Zone of southwestern Ethiopia, approximately 513 km from Addis Ababa and 36 km from Bedele, the zonal administrative center. The district lies between 8°13′33.7″ and 8°33′55.0″ N latitude and 35°59′59.7″ and 36°15′15.8″ E longitude, with an altitude ranging from 1,013 to 2,200 m above sea level (m a. s. l.). The area receives an annual rainfall of 1,500–2,200 mm and is characterized by a humid to sub-humid climate. The dominant soil types are Nitisols, Acrisols, Lithosols, and Cambisols. Agriculture in the district is predominantly based on mixed crop–livestock production systems.

2.1.2. Gechi District

Gechi District is situated in the Buno Bedele Zone and is bordered by Didessa District to the south, the Didessa River to the west, Bedele District to the north, and Jimma Zone to the east. It is located approximately 465 km from Addis Ababa and 18 km from Bedele town. The district is situated at an altitude ranging from 1,277 to 2,467 m above sea level and is located at approximately 8°17′ N latitude and 36°34′ E longitude. The area receives an average annual rainfall of 1,500–2,100 mm. Crop production is the dominant agricultural activity and serves as the primary livelihood of the farming community.

2.2. Experimental Materials and Design

Six improved Kabuli chickpea (Cicer arietinum L.) varieties, namely Ejeri, Asnake, Dhera, Koka, Habru, and Hora, were used as experimental materials. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications at each location.

Each experimental plot measured 6 m^2 (3 m × 2 m) and consisted of five rows spaced 0.40 m apart. A spacing of 0.50 m was maintained between adjacent plots, while blocks were separated by 1.0 m. The three central rows were used for data collection, whereas the two outer rows served as border rows to minimize border effects.

The experimental fields were prepared through three plowings using oxen-drawn implements prior to planting. Seeds were sown at a rate of 100 kg ha^{-1}, and NPS fertilizer was applied at a rate of 50 kg ha^{-1} following national recommendations for chickpea production. All other agronomic and crop protection practices, including weed, insect, and disease management, were carried out uniformly across all treatments according to the recommended production package for the crop.

Table 1. Description of six Kabuli chickpea varieties used in the experiment.

Varieties	Altitude Range	Type	Year of Release	Source
Ejeri	1800-2700	Kabuli	2005	DzARC/EIAR
Asneke	1800-2700	Kabuli	2021	DzARC/EIAR
Dhera	1800-2700	Kabuli	2016	DzARC/EIAR
KOKA	1800-2700	Kabuli	2019	DzARC/EIAR
Habru	1800-2700	Kabuli	2004	DzARC/EIAR
Hora	1800-2700	Kabuli	2016	DzARC/EIAR

Note: DzARC: DebrezeitAgricultural Research Center, EIAR: Ethiopia Institute of Agricultural Research
Source: Crop Variety Register

2.3. Data Collected

Data were recorded on phenological, growth, yield, and yield-related traits, including days to flowering, days to maturity, plant height (cm), number of pods per plant, number of seeds per pod, hundred-seed weight (g), and grain yield (kg ha^{-1}).

2.4. Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) using R statistical software. Mean comparisons among varieties were performed using the Least Significant Difference (LSD) test at the 5% probability level whenever significant differences were detected. Combined analysis across locations and years was conducted to evaluate varietal performance and stability under varying environmental conditions.

3. Result & Discussion

3.1. Combined Analysis of Variance

The combined analysis of variance (ANOVA) revealed highly significant ($P < 0.01$) effects of variety, location, and variety × location interaction on grain yield. The significant varietal effect indicates the existence of considerable genetic variability among the tested Kabuli chickpea varieties, resulting in differences in yield performance. Likewise, the significant location effect demonstrated that environmental conditions varied across the test sites and substantially influenced grain yield.

The highly significant variety × location interaction suggests that the tested varieties responded differently to changes in environmental conditions. This indicates that the relative performance of the varieties was not consistent across locations, reflecting differences in adaptability and yield stability. Such variation is common in multi-environment trials, where genotype performance is influenced by both genetic potential and environmental factors.

The mean grain yield of the varieties varied considerably across locations, indicating that the expression of yield-related traits was affected by environmental conditions. Nevertheless, the superior performance of some varieties across environments suggests their potential for wider adaptation and stable production. Therefore, evaluating varieties under diverse environments is essential for identifying high-yielding and broadly adapted chickpea cultivars suitable for recommendation in the target areas.

This finding is consistent with previous reports that grain yield in chickpea is strongly influenced by genotype, environment, and their interaction, emphasizing the importance of multi-location evaluation in varietal selection programs.

Table 2. ANOVA for yield and yield related traits for six (6) Kabuli chickpea varieties over two locations for two consecutive years.

Source of variation	Mean squares							
	Df	DF (days)	DM (days)	PH (cm)	NPP	NSP	HSW (g)	GY ($kgha^{-1}$)
Replication	2	2.056^{ns}	0.06^{ns}	28.1^{ns}	24.54^{ns}	0.096^{ns}	28.29^{ns}	112296^{ns}
Varieties	5	241.56^{***}	247.92^{***}	129.1^{***}	1011.03^{***}	0.055^{ns}	39.93^{**}	828065^{***}

Source of variation	Mean squares							
	Df	**DF (days)**	**DM (days)**	**PH (cm)**	**NPP**	**NSP**	**HSW (g)**	**GY (kgha^{-1})**
Location	1	180.50^{***}	93.39^{***}	14730.0^{***}	185.82^{*}	0.21^{*}	78.13^{**}	1909565^{***}
Year	1	0.056^{ns}	0.06^{ns}	3662.3^{***}	2159.71^{***}	0.004^{ns}	17.01^{ns}	12223460^{***}
Var: Loc	5	16.53^{ns}	341.79^{***}	30.0^{ns}	77.93^{ns}	0.07^{ns}	22.59*	417502^{***}
Var: Year	5	0.422^{ns}	0.06^{ns}	118.6^{***}	183.09^{**}	0.06^{ns}	10.15^{ns}	184253^{*}
Var: Loc: Yr	5	6.028^{ns}	0.06^{ns}	2375.6^{***}	125.47^{*}	0.07^{ns}	11.29^{ns}	171489^{*}
Residual	46	5.722	0.06	16.7	45.81	0.033	8.87	82664

Note: Df=degrees of freedom, DF=days to flowering, DM=days to maturity, PH=Plant height, NPP=number of pod per plant, NSP=number of seed per pod *** significant (0.001), *=significant at (0.05) & ns= non-significant

3.2. Grain Yield Performance of Kabuli Chickpea Varieties

The combined analysis of variance across two locations and two consecutive cropping seasons revealed highly significant ($P < 0.01$) differences among the tested Kabuli chickpea varieties for grain yield (kg ha^{-1}) (Table 3). The observed variation in grain yield indicates the existence of substantial genetic differences among the varieties and their differential response to the prevailing environmental conditions.

Among the tested varieties, KOKA produced the highest mean grain yield (1568.04 kg ha^{-1}), followed by Habru (1271.81 kg ha^{-1}), whereas Hora recorded the lowest grain yield (865.83 kg ha^{-1}). The superior performance of KOKA suggests its greater yield potential and better adaptation to the agro ecological conditions of the study areas. In contrast, the relatively lower yield of Hora may indicate limited adaptability to exploit the available environmental resources.

The significant variation in grain yield among varieties is consistent with previous findings reported by [10], who observed grain yield differences ranging from 520 to 2010 kg ha^{-1} among improved chickpea varieties evaluated across different environments. Similarly, [9] reported significant varietal differences in grain yield, emphasizing the influence of genotype and environment on chickpea productivity.

The consistently superior performance of KOKA across most testing environments suggests that the variety possesses desirable genetic attributes for yield and adaptability. Such stable performance across locations indicates its potential suitability for wider cultivation in the Buno Bedele Zone and similar agro ecological areas.

The results further demonstrate the importance of multi-location varietal evaluation for identifying high-yielding, adaptable, and stable chickpea varieties that can enhance productivity and improve farmers' livelihoods.

Table 3. *Mean grain yield (kg ha^{-1}) of six Kabuli chickpea varieties over two locations for two main cropping seasons (2023-2024).*

Grain yield (kgha^{-1})					
Varieties	**Chora-2023**	**Chora 2024**	**Gechi-2023**	**Gechi 2024**	**Overall Means**
Ejeri	432.53^{d}	1316.67^{c}	457.70^{bc}	1693.33^{a}	975.06^{b}
Asneke	400.99^{d}	1730.45^{bc}	351.90^{c}	1246.67^{b}	932.39^{b}
Dhera	1066.54^{b}	1426.67^{c}	638.89^{b}	1453.33^{ab}	1146.36^{ab}
KOKA	1554.32^{a}	2460.12^{a}	1077.83^{a}	1180.00^{b}	1568.04^{a}
Habru	1010.43^{bc}	2140.56^{ab}	623.46^{b}	1313.33^{b}	1271.81^{ab}
Hora	611.73^{cd}	1323.33^{c}	348.25^{c}	1180.00^{b}	865.83^{b}
GM	846.09	1732.78	583.00	1344.44	1126.58
LSD (0.05)	402.52	642.83	262.91	297.65	477.88
CV%	26.15	20.39	24.79	12.17	31.48

Grain yield (kgha^{-1})					
Varieties	**Chora-2023**	**Chora 2024**	**Gechi-2023**	**Gechi 2024**	**Overall Means**
P-value	***	*	**	*	*

Note: GM= grand mean, LSD=least significant difference, CV= coefficient of variation,** and ***, significance at 0.01 and 0.001 probability levels respectively.

3.3. Performance of Phenological, Growth, and Yield-Related Traits

The combined analysis across locations and years showed significant ($P < 0.05$) differences among the tested Kabuli chickpea varieties for most phenological and yield-related traits, including days to flowering, days to maturity, number of pods per plant, number of seeds per pod, and hundred-seed weight. However, plant height was not significantly affected by varietal differences. These results indicate the presence of considerable genetic variability among the evaluated varieties.

Days to 50% Flowering (DF): Days to flowering varied significantly among varieties. Early flowering is an important trait in moisture-limited environments because it enables plants to escape terminal drought stress. The observed variation among varieties suggests differences in their adaptation to the growing environments and their potential suitability for areas prone to moisture stress.

Days to 90% Maturity (DM): Significant differences ($P < 0.01$) were observed for days to maturity. Ejeri (136.52 days) and Habru (136.67 days) were the earliest maturing varieties, whereas Dhera (147.52 days) and Hora (143.00 days) required a longer period to reach maturity. Early maturity is advantageous in areas where late-season moisture stress frequently limits crop productivity.

Number of Pods per Plant (NPP): The number of pods per plant was significantly influenced by variety and location interaction. Koka produced the highest number of pods per plant (41.83), followed by Habru (26.58), while Asnake recorded the lowest value (16.89). Since pod number is a major yield component, higher pod production contributes positively to grain yield. Number of Seeds per Pod (NSP): Significant differences were also observed for the number of seeds per pod. Koka recorded the highest value (1.29), followed by Habru (1.21), whereas Asnake had the lowest number of seeds per pod (1.11).

Hundred-Seed Weight (HSW): Hundred-seed weight differed significantly among varieties. Koka produced the highest hundred-seed weight (35.42 g), followed by Asnake (32.92 g), while Hora recorded the lowest value (30.42 g). The variation in seed weight indicates differences in seed size among varieties and contributes to the observed differences in grain yield performance. Overall, KOKA consistently exhibited superior performance for most yield-related traits, which contributed to its highest grain yield across the tested environments. This result agrees with previous reports that significant varietal differences exist for key agronomic traits in chickpea [13].

Table 4. *Mean yield related traits of six Kabuli chickpea varieties at Chora & Gechi districts for two consecutive years.*

Varieties	DF (days)	DM (days)	PH (cm)	NPP	NSP	HSW (g)
Ejeri	62.25^{c}	136.52^{c}	64.01	24.17^{bc}	1.20^{ab}	32.33^{b}
Asneke	59.17^{d}	137.55^{c}	65.10	16.89^{c}	1.11^{b}	32.92^{ab}
Dhera	69.50^{a}	147.50^{a}	70.74	20.83^{bc}	1.19^{ab}	32.08^{b}
KOKA	60.42^{cd}	137.00^{c}	64.78	41.83^{a}	1.29^{a}	35.42^{a}
Habru	58.00^{d}	136.67^{c}	61.51	26.58^{b}	1.21^{ab}	30.58^{b}
Hora	66.50^{b}	143.00^{b}	68.32	17.78^{c}	1.12^{b}	30.42^{b}
GM	62.64	139.69	65.74	24.68	1.19	32.29
LSD (0.05)	2.42	4.33	18.84	8.23	0.17	2.76
CV%	4.74	3.80	35.14	20.87	17.56	10.49
P-value	**	**	NS	***	**	**

Note: GM= grand mean, LSD=least significant difference, CV= coefficient of variation,** and ***, significance at 0.01 and 0.001 probability levels respectively.

3.4. Additive Main Effects and Multiple Interaction (AMMI) Model

The AMMI analysis of six Kabuli chickpea varieties evaluated across four environments showed that environmental effects accounted for the largest proportion of the total variation (46.87%), followed by genotypic effects (13.66%) and genotype × environment interaction (GEI) effects (13.09%) (Table 5). The large contribution of the environment indicates considerable differences among the test environments, which strongly influenced varietal performance.

The magnitude of the GEI effect was comparable to that of the genotypic effect, suggesting that the varieties responded differently across environments and highlighting the importance of evaluating genotypes under diverse conditions. The first Interaction Principal Component Axis (IPCA-1) explained 77.70% of the GEI sum of squares, while IPCA-2 accounted for an additional 21.30%. Together, the two IPCAs captured 99.00% of the total GEI variation.

Furthermore, the mean squares of both IPCA-1 and IPCA-2 were significant, indicating that the interaction pattern was meaningful and could be effectively explained by these two principal components. The high proportion of GEI variation explained by IPCA-1 and IPCA-2 demonstrates the suitability of the AMMI model for assessing varietal stability and adaptability across the tested environments.

Table 5. AMMI analysis for grain yield of six (6) kabuli chickpea varieties tested.

SOV	Df	SS	MS	Variance (%)	Cumulative (%)
REP (ENV)	8	1812533	226567^{ns}	5.98	
ENV	3	14203615	4734538^{***}	46.87	
GEN	5	4140323	828065^{*}	13.66	
ENV: GEN	15	3967118	264475^{*}	13.09	
PCA-1	7	30812119	440174^{**}	77.7	77.7
PCA-2	5	845541	169108*	21.3	99.0
Residuals	40	2214607	55365		
Total	86	30305315	352387		

Note: *** Significant difference at (P≤0.001), SOV=source of variation, Df=degree of freedom, SS=sum of square, MS=mean sum of square, PCA=principal component of axis

4. Conclusion & Recommendation

Six improved Kabuli chickpea varieties were evaluated for grain yield, agronomic performance, and adaptability across two locations in the Buno Bedele Zone of southwestern Oromia, Ethiopia. The results demonstrated significant differences among varieties for grain yield and several important agronomic traits, confirming the presence of genetic variability among the tested materials. Among the evaluated varieties, Koka and Habru consistently showed superior grain yield and favorable agronomic performance compared with the other varieties.

Therefore, KOKA and Habru are recommended for production in Chora and Gechi districts and other areas with similar agroecological conditions in the Buno Bedele Zone. However, further on-farm verification and demonstration trials involving farmers are recommended before wider-scale dissemination to confirm their performance and farmer acceptance under broader production conditions.

Abbreviations

AMMI	Additive Main Effects and Multiplicative Interaction
ANOVA	Analysis of Variance
CSA	Central Statistical Agency
CV	Coefficient of Variation
DF	Days to Flowering
DM	Days to Maturity
DZARC	Debre Zeit Agricultural Research Center
EIAR	Ethiopian Institute of Agricultural Research
ENV	Environment

GEI	Genotype × Environment Interaction
GM	Grand Mean
GY	Grain Yield
HSW	Hundred-Seed Weight
IPCA	Interaction Principal Component Axis
LSD	Least Significant Difference
MS	Mean Square
NPP	Number of Pods per Plant
NSP	Number of Seeds per Pod
OARI	Oromia Agricultural Research Institute
PH	Plant Height
RCBD	Randomized Complete Block Design
SS	Sum of Squares
SOV	Source of Variation

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Author Contributions

Mohammed Tesiso: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Resources, Software, Methodology, Writing – original draft

Garoma Firdisa: Supervision, Visualization, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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