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Evaluation of Adaptability and Morpho-Agronomic Attributes of Black Cumin (*Nigella sativa* L.) Varieties in the Buno Bedele Zone, Southwestern Ethiopia

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Abstract

Black cumin (*Nigella sativa* L.) is a premier spice and strategic cash crop in Ethiopia, yet the adoption of improved varieties remains critically low in the southwestern highlands. This study was conducted in the Buno Bedele Zone across three representative districts to evaluate the adaptability and yield performance of improved black cumin varieties. Six improved varieties (Darbera, Soressa, Qanani, Kena, Urgessa, and Gemechis) along with a local check were evaluated using a Randomized Complete Block Design (RCBD) with three replications. The analysis of variance (ANOVA) revealed highly significant ($P < 0.01$) differences among the varieties for most traits, including days to flowering, days to maturity, number of capsules per plant, number of branches, and seed yield. However, plant height showed non-significant ($P > 0.05$) variation. The highest seed yield was achieved by the variety Urgessa (1.03 t ha^{-1}), followed by Darbera (0.88 t ha^{-1}), while the local check exhibited the lowest yield (0.47 t ha^{-1}). The superior performance of Urgessa and Darbera indicates their high genetic potential and robust adaptability to the high-rainfall conditions of the study area. Therefore, Urgessa and Darbera are recommended for large-scale production and scaling up in the Buno Bedele Zone and similar agro-ecologies to enhance smallholder productivity.

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Adaptability, Nigella sativa L., Improved varieties, Seed yield

Introduction

Black cumin (*Nigella sativa* L.), originating from the Eastern Mediterranean and Egypt, is currently cultivated in numerous countries worldwide, including Ethiopia (Hailemichael *et al.,* 2016; Moussa *et al.,* 2024).

It is an annual, erect herbaceous medicinal plant prized for its pungent seeds, which are rich in bioactive compounds such as thymoquinone (Dame *et al.,* 2023; Khan *et al.,* 2025). According to Dessie *et al.,* (2019), black cumin thrives in altitudinal ranges between 1500 and 2500 m a.s.l. and requires 120–400 mm of rainfall during the growing season for optimum productivity.

Ethiopia possesses diverse and favorable agro-ecological zones suitable for high-value spices, including black cumin (Shariq *et al.,* 2015; Wegayehu *et al.,* 2022). Several spice varieties, such as white cumin, pepper, turmeric, fenugreek, and ginger, are grown across the country for both domestic consumption and export (Hailemichael *et al.,* 2016; Solomon *et al.,* 2024). Consequently, Ethiopia is recognized as a leading spice producer and consumer, ranking first in Africa and seventh globally (FAOSTAT, 2019; Banu, 2021).

In Ethiopia, black cumin is primarily cultivated in the Amhara, Oromia, Tigray, and SNNP regions (Gashaw, 2020). It is essential for flavoring traditional foods, oil production for perfumes, and diverse medicinal applications (Ahmed & Teshome, 2021). Beyond its culinary uses, black cumin oil is utilized in the manufacturing of soaps, lotions, nutraceuticals, and cosmeceuticals (Jibat *et al.,* 2019; Naeem *et al.,* 2025).

Despite these favorable conditions, the national average productivity of black cumin remains low at approximately 0.79 t ha^{-1} (Dame *et al.,* 2023). This yield gap is attributed to several constraints, including the scarcity of improved varieties, improper crop management, high weed incidence, and inadequate post-harvest handling (Assefa & Bariso, 2020; Amdie & Teshome, 2021).

While improved varieties can yield between 0.9 and 1.6 t ha^{-1} under research conditions, farmers' yields remain significantly lower. In the Buno Bedele Zone, despite suitable agro-ecological conditions, black cumin remains an underutilized crop with a critical lack of research on varietal adaptability.

Therefore, this study was initiated to evaluate and select the best-adapted improved black cumin varieties for the Buno Bedele Zone and similar agro-ecologies.

Materials and Methods

Description of the Study Areas

The experiment was conducted during the 2023–2024 main cropping seasons across two representative districts in the Buno Bedele Zone, Southwestern Oromia, Ethiopia: Gechi and Dabo Hana. Gechi district is located approximately 465 km from Addis Ababa and 18 km from Bedele town, experiencing an annual rainfall range of 1500–2100 mm (Abdeta *et al.,* 2023). Dabo Hana district is situated 521 km from the capital and 38 km from Bedele, with annual rainfall ranging from 900 to 2200 mm. Both locations represent mid-to-high altitude agro-ecologies characterized by fertile Nitisols, which are highly suitable for high-value spice production.

Experimental Materials and Design

Six improved black cumin varieties (Darbera, Soressa, Qanani, Kena, Urgessa, and Gemechis) along with a Local check were evaluated for two consecutive years. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The gross plot size was 2.0 m x 2.4 m (4.8 m^2), consisting of eight rows with an inter-row spacing of 30 cm.

Field Management and Procedures

Seeds were sown by hand-drilling at a recommended rate of 15 kg ha^{-1}. Blended NPS fertilizer was applied at a rate of 100 kg ha^{-1} at the time of planting. Urea was applied at a rate of 100 kg ha^{-1} in two split doses: half at planting and the remaining half as a top dressing during the peak vegetative stage. All other agronomic practices, including conventional land preparation, timely weeding, and pest management, were performed uniformly across all plots to ensure optimum crop growth.

Data Collection and Statistical Analysis

Days to 50% flowering were determined by calculating the number of days from the sowing date to the date when 50% of the plants in each plot reached anthesis. Agronomic and yield-related data were collected from five randomly sampled plants per net plot area, and the average values were used for statistical analysis. Plant height (cm) was measured from the soil surface to the tip of the highest capsule at physiological maturity. The number of primary and secondary branches was recorded by counting all branches originating from the main stem and primary branches, respectively.

The number of capsules per plant was determined by counting all capsules on the sampled plants, while the number of seeds per capsule was recorded by counting all seeds within those capsules. Seed yield per hectare (t ha^{-1}) was calculated by converting the seed yield obtained from the net harvestable area of each plot. All collected data were subjected to analysis of variance (ANOVA) following the procedures described by Gomez and Gomez (1984). Mean comparisons were performed using Duncan's Multiple Range Test (DMRT) at a 5% level of significance.

Results and Discussion

Analysis of Variance (ANOVA)

The combined analysis of variance revealed highly significant ($P < 0.01$) differences among the varieties for days to flowering, days to maturity, number of branches per plant, number of capsules per plant, number of seeds per capsule, and seed yield (Table 2). However, plant height showed non-significant ($P > 0.05$) variation among the tested genotypes. These findings indicate the presence of substantial genetic variability among the black cumin varieties, which is essential for selecting adaptable genotypes for the southwestern highlands of

Ethiopia. Similar results were reported by Assefa and Bariso (2020), who highlighted the importance of varietal selection in spice improvement.

Phenological and Growth Parameters

Days to 50% Flowering and 90% Physiological Maturity

The results revealed that days to flowering and maturity were highly significantly ($P < 0.01$) influenced by variety, environment, and their interaction (Table 2). Flowering time ranged from 56.56 to 68.33 days, while maturity ranged from 91.67 to 110 days. The longest duration to flowering was recorded for Soressa (68.33 days), followed by Darbera (65.00 days), whereas Qanani flowered earliest at 60.00 days. Similarly, the Darbera variety was the latest to mature (110.00 days), while the Local variety matured earliest at 91.67 days. These variations indicate substantial genetic diversity among the genotypes and their differential response to environmental cues. These findings are supported by Assefa and Bariso (2020) and Amdie and Teshome (2021). Similarly, Bekele and Georgis (2023) and Gebremedin *et al.,* (2023) reported that phenological traits in black cumin are highly dependent on varietal characteristics and agro-ecological conditions.

Plant Height (cm)

Analysis of variance revealed non-significant ($P > 0.05$) differences among the varieties for plant height. Plant height ranged from 25.25 cm (Urgessa) to 32.78 cm (Local). This lack of significant variation is consistent with the findings of Amdie and Teshome (2021) and Dema *et al.,* (2023), who also reported no significant height differences among released black cumin varieties. In contrast, Assefa and Girma (2016) observed greater plant heights ranging from 32 cm to 41.5 cm, suggesting that environmental factors such as soil fertility and rainfall distribution during the vegetative stage significantly influence height expression.

Yield Component Parameters

Number of Branches and Capsules per Plant

The number of branches was highly significantly ($P < 0.01$) affected by variety and location (Table 2). The number of branches per plant ranged from 1.33 to 5.00, with the highest number of primary branches recorded for the Darbera variety. Regarding the number of capsules per plant, highly significant ($P < 0.01$) variations were observed. The highest number of capsules was exhibited by Urgessa (18.87), which was statistically at par with Soressa (18.67) and Darbera (18.33). Conversely, the Kena variety recorded the lowest number of capsules (15.00). These findings align with Ahmed and Teshome (2021) and Assefa and Bariso (2020), who noted that capsule number per plant is a critical yield determinant that varies across genotypes and environments. Furthermore, Assefa and Girma (2016) indicated that black cumin seed yield is positively correlated with the number of capsules and primary branches per plant, explaining the superior yield of Urgessa in the current study.

Seed Yield Performance and Advantage

The highest seed yield was recorded for the variety Urgessa (1.03 t ha^{-1}) followed by Darbera (0.88 t ha^{-1}) as shown in Table 3. In contrast, the local check exhibited the lowest productivity 0.47 t ha^{-1}). The superior performance of Urgessa represents at 119.15% Yield advantage over the local check. This yield superiority is directly linked to its high number of capsules per plant and seeds per capsule. These results align with the findings of Jaleto *et al.,* (2025), who identified high-yielding black cumin genotypes with robust adaptability.

Varietal Response to Disease Incidence

The study also evaluated the varieties for their reaction to Powdery Mildew (PM), which is the most prevalent fungal disease affecting black cumin in the high-humidity agro-ecologies of Southwestern Ethiopia.

The results, as presented in Table 4, showed that all tested varieties, including the local check, exhibited a high level of resistance (score of 5r) to the disease during the experimental period. This resistance played a crucial role in maintaining a healthy leaf canopy, which facilitated optimal photosynthesis and carbohydrate translocation to the developing capsules.

Correlation Analysis among Growth and Yield Components

The Pearson correlation analysis revealed a strong and positive association among most yield components, whereas plant height exhibited a weak and non-significant correlation with seed yield (Table 5). Highly significant and positive correlations were observed between seed yield and its primary components.

Table.1 Description of black cumin varieties evaluated in the study.

No	Variety	Year of Release	Breeder Source
1	Darbera	2006	Sinana Agricultural Research Center (SARC/IQQO)
2	Soressa	2016	Sinana Agricultural Research Center (SARC/IQQO)
3	Qanani	2009	Sinana Agricultural Research Center (SARC/IQQO)
4	Kena	2009	Sinana Agricultural Research Center (SARC/IQQO)
5	Urgessa	2016	Sinana Agricultural Research Center (SARC/IQQO)
6	Gemechis	2016	Sinana Agricultural Research Center (SARC/IQQO)
7	Local check	-	Farmers' cultivar

Source: Variety Registration Book (MoA, 2021).

Table.2 Combined mean square values for phenological, growth, and yield components of black cumin varieties.

SV	df	DF	DM	PH	NBPP	NCPP	NSCP	SY
Replication	2	33.33ns	5.66ns	0.19ns	0.76ns	0.43ns	0.13ns	0.01ns
Variety	6	838.09**	49.48**	97.78**	19.43**	23.54**	0.56**	0.28**
Location	1	131.25**	0.37ns	5.25**	189.00**	390.01**	0.34**	0.15**
Year	1	43.75*	57.56**	1.75ns	175.00**	374.04**	0.08*	0.04*
Error	64	9.84	0.50	0.65	0.14	0.60	0.08	0.02

Note: SV = Source of Variation; df = Degrees of Freedom; DF = Days to 50% Flowering; DM = Days to 90% Maturity; PH = Plant Height; NBPP = Number of Branches per Plant; NCPP = Number of Capsules per Plant; NSCP = Number of Seeds per Capsule; SY = Seed Yield (t ha^{-1}); ns = non-significant; * = significant ($P < 0.05$); ** = highly significant ($P < 0.01$).

Table.3 Combined mean seed yield (t ha^{-1}) and yield advantage of improved black cumin varieties over two years (2023–2024) at Dabo Hana and Gechi districts.

Varieties	2023	2024	Combined	Yield Advantage (%)
Urgessa	0.92^{a}	1.13^{a}	1.03^{a}	119.15
Darbera	0.70^{b}	1.05^{b}	0.88^{b}	87.23
Qanani	0.65^{b}	0.85^{b}	0.75^{b}	59.57
Kena	0.60^{b}	0.62^{b}	0.62^{b}	31.91
Gemechis	0.52^{c}	0.67^{c}	0.60^{c}	27.66
Soressa	0.57^{b}	0.68^{b}	0.58^{b}	23.40
Local check	0.41^{c}	0.53^{c}	0.47^{c}	-
LSD (0.05)	0.16	0.22*	0.18*	-
CV (%)	13.58	23.55	13.27	-
P-Value	**	**	**	-

Note: Yield Advantage (%) was calculated relative to the local check; LSD (0.05) = Least Significant Difference; CV (%) = Coefficient of Variation; ** = Highly Significant at $P < 0.01$. Means followed by the same letter within a column are not significantly different.

Table.4 Combined mean of phenological, growth, and yield components of blackcumin varieties over two years (2023–2024) at Dabo Hana and Gechi districts.

Varieties	DF (days)	DM (days)	PH (cm)	NBPP (No.)	NCPP (No.)	NSCP (No.)	Disease (PM)
Darbera	65.00^{a}	110.00^{a}	29.72	8.00^{a}	18.33^{a}	12.00^{b}	5r
Soressa	68.33^{a}	115.00^{a}	27.50	6.67^{a}	18.67^{a}	8.67^{c}	5r
Qanani	60.00^{b}	103.00^{b}	31.11	3.33^{a}	15.67^{a}	10.00^{c}	5r
Kena	55.00^{b}	96.67^{c}	29.44	3.00^{b}	15.00^{a}	12.67^{c}	5r
Urgessa	55.00^{b}	96.67^{c}	25.25	4.00^{b}	18.87^{b}	25.67^{a}	5r
Gemechis	56.67^{b}	100.00^{c}	29.72	4.67^{b}	15.67^{b}	16.67^{b}	5r
Local check	56.56^{b}	91.67^{c}	32.78	3.33^{b}	15.67^{b}	15.00^{b}	5r
LSD (0.05)	6.60	7.12	ns	2.32	1.74	5.19	-
CV (%)	5.29	3.86	19.32	27.64	6.03	20.27	-
P-Value	**	**	ns	**	**	**	-

Note: DF = Days to 50% Flowering; DM = Days to 90% Maturity; PH = Plant Height; NBPP = Number of Branches per Plant; NCPP = Number of Capsules per Plant; NSCP = Number of Seeds per Capsule; PM = Powdery Mildew; r = resistant; ns = non-significant; ** = highly significant ($P < 0.01$).

Table.5 Pearson correlation coefficients among phenological, growth, and yield components of black cumin varieties.

Trait	DF	DM	PH	NBPP	NCPP	NSCP	SY
DF	1						
DM	0.99**	1					
PH	0.04ns	0.04*	1				
NBPP	0.63**	0.63**	0.22ns	1			
NCPP	0.33*	0.33**	0.21ns	0.79**	1		
NSCP	0.19ns	0.19ns	0.79**	0.85*	0.79**	1	
SY	0.62**	0.62**	0.69**	0.68*	0.76**	0.89**	1

Note: DF = Days to 50% Flowering; DM = Days to 90% Maturity; PH = Plant Height; NBPP = Number of Branches per Plant; NCPP = Number of Capsules per Plant; NSCP = Number of Seeds per Capsule; SY = Seed Yield; ns = non-significant; * = significant ($P < 0.05$); ** = highly significant ($P < 0.01$).

Specifically, the number of branches per plant showed a strong positive correlation with the number of capsules per plant (r = 0.79**), the number of seeds per capsule (r = 0.85**), and overall seed yield (r = 0.68**).

Furthermore, a significant positive association was established between the number of capsules per plant and the number of seeds per capsule (r = 0.79**), as well as with seed yield (r = 0.67**). Notably, the number of seeds per capsule exhibited the strongest positive relationship with seed yield (r = 0.89**), indicating that it is the most critical yield-contributing trait in black cumin. In conclusion, the yield components of the evaluated black cumin varieties showed a robust positive relationship with seed yield, implying that these traits directly influence the overall productivity. Therefore, prioritizing these components during selection and breeding programs can effectively enhance the seed yield of black cumin in the study area.

Conclusion and Recommendations

The adaptability trial conducted across the Dabo Hana and Gechi districts of the Buno Bedele Zone highlights the immense potential of improved black cumin varieties to transform smallholder productivity in Southwestern Ethiopia. The results demonstrated highly significant genetic variability among the tested varieties, with the local landrace showing the lowest productivity, indicating a critical need for variety replacement in the region.Among the evaluated varieties, Urgessa and Darbera emerged as the most superior genotypes, achieving combined seed yields of 1.03 t ha^{-1} and 0.88 t ha^{-1}, respectively. Notably, Urgessa exhibited a remarkable 119.15% yield advantage over the local check (0.47 t ha^{-1}). This superior performance is a direct result of its high genetic potential for primary yield components, specifically the number of seeds per capsule and the number of capsules per plant. Furthermore, both varieties demonstrated robust resistance to Powdery Mildew, ensuring a healthy crop stand under high-humidity conditions. In conclusion, Urgessa and Darbera are highly recommended for immediate demonstration, popularization, and large-scale distribution to farmers in the Buno Bedele Zone and similar agro-ecologies. To fully exploit their genetic potential, agricultural extension services should integrate these varieties with optimized agronomic packages, including site-specific fertilizer rates and timely weeding. Future research focusing on seed systems and market value-chain development is also recommended to ensure that the increased productivity translates into enhanced household income and food security for the region.

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