International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM September 2023, 14(9):1225-1233 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR4379

Research Article Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2023.4379

Estimation of Variability, Heritability, and Genetic Advance among Ethiopian Coriander (*Coriandrum sativum* L.) Accessions

Gizaw Wegayehu Tilahun[1], Dasta Tsagaye Galalcha[1], Fekadu Gebretensay Mengistu[2], Demis Fikire Limeneh[1], Awoke Ali Zeleke[3] and Nimona Fufa Hundie[1]

[1]Kulumsa Agricultural Research Center (KARC), Asella, P.O.Box 489, Ethiopia
[2]Debre Zeit Agricultural Research Center, DebreZeit, P.O.Box 32, Ethiopia
[3]Fogera National Rice Research and Training Center, Wereta, Ethiopia

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Corresponding gizawweg21@gmail.com

0000-0001-8221-9652

ABSTRACT

A field experiment was conducted at the Kulumsa Agricultural Research Center in Southeast Ethiopia during the *meher* season (July to November 2019 and 2020) to evaluate the extent of variability, heritability, and genetic advance of eight yield and yield-related variables among 25 Ethiopian coriander accessions. A 5×5 simple lattice with two replications was used to arrange the accessions. The combined analysis of variance revealed highly significant differences ($P < 0.01$) for the eight examined traits. The results showed a large degree of variation in all traits that were studied, pointing to the possibility of simultaneously boosting yield and traits that are related to yield. The estimated broad sense heritability (H^2b) ranged from low for seeds per umbel and thousand-seed weight during the first and second growing seasons, respectively, to very high for seed yield (t ha^{-1}), number of umbel $plant^{-1}$, and number of umbellets $umbel^{-1}$. The seed yield $plant^{-1}$ (g), seed yield (t ha^{-1}), and number of umbellets $umbel^{-1}$ were shown to have the highest genetic advances as a percentage of the mean (GAM (%)). According to these findings, cultivar selection based on traits of high H^2b in combination with high GAM (%) could enhance offspring performance and increase coriander yields. The results had practical implications for breeders and farmers. More investigation is compulsory to identify processing qualities and assess the phenotypic and genetic diversity among Ethiopian coriander accessions.

KEYWORDS: Coriander accession, Ethiopia, GCV, PCV, yield

***Citation* (VANCOUVER):** Tilahun et al., Estimation of Variability, Heritability, and Genetic Advance among Ethiopian Coriander (*Coriandrum sativum* L.) Accessions. *International Journal of Bio-resource and Stress Management,* 2023; 14(9), 1225-1233. HTTPS://DOI.ORG/10.23910/1.2023.4379.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 17th July 2023 RECEIVED in revised form on 24th August 2023 ACCEPTED in final form on 09th September 2023 PUBLISHED on 18th September 2023

1. INTRODUCTION

Coriander (*Coriandrum sativum* L.) is an annual herb in the Apiaceae family with yellowish-brown fruits (Hedburg and Hedburg, 2003; Yeung and Bowra, 2011). Coriander is native to the Mediterranean and Western Asian regions (Coskuner and Karabala, 2007; Burdock and Carabin, 2009) and is now widely cultivated as a spice globally (Maroufi et al., 2010). It is a crop with global adaptation, growing well in a wide range of soils, climates, and extreme latitudes and elevations (Guenther, 1972; Purseglove et al., 1981; Simon, 1990; Verma et al., 2011). Coriander is used in the culinary, medicine, perfumery, beverage, and pharmaceutical industries (Jansen, 1981; Diederichsen, 1996; Delaquis et al., 2002; Kubo et al., 2004). Rich in vitamins and other minerals, its green leaves are used in the form of vegetables and salads (Kalemba and Kunicka, 2003). Coriander seeds are a spice used as a source of carotene, thiamine, riboflavin, niacin, tryptophan, vitamin B6, folic acid, iron, manganese, magnesium, fiber, and linalool-rich essential oils (Ensminger and Esminger, 1986; Holland et al., 1991) The seeds are readily available and sold in every market in Ethiopia at a high price, and the leaves and immature fruits are used as ingredients for the preparation of "data", a traditional spice used to eat meat, fish, and boiled potatoes in the Southern parts of Ethiopia (Kassahun, 2018; Anonymous, 2022).

Ethiopia is the center of the primary diversity of coriander (Jansen, 1981). The country has an ideal climate and agroecology for cultivating coriander, which is mostly grown by smallholder farmers and commercial producers. It is dominantly grown in the regions of Amhara, Oromia, Southern Nations Nationalities and Peoples, and Gambela. Coriander has local names: Amharic (dembilal), Oromiffa (debo, shucar), Tigrinya (tsagha, zagda), and Konsonya (tibichota) in Ethiopia. These names indicate the plant's economic significance in the diverse societies of the nation (Jansen, 1981; Goetsch et al., 1984). Coriander productivity varies with agroecology and variety, and Ethiopia's national average productivity is 0.25 t ha-1 (Kifelew et al., 2017). However, released varieties such as 'Indium 01', 'Walta I', 'Denkinesh', 'Batu', and 'Tulu' have the potential to produce yields ranging from 0.5 to 2.6 t ha-1 in farmers' fields and research trials (Anonymous, 2018).

Effective selection criteria for crop improvement require research into traits that are less influenced by the environment. The level of genetic variation in the underlying population impacts the appropriateness of genotypes and is important in any plant breeding effort (Singh, 2001). The degree of selection and heritability of a trait depends on the genetic variation of the population. Knowing the type and degree of variability, heritability, and genetic advancement in the experimental material is critical for initiating a successful breeding program. Thus, it is important to assess the indicators of variability: genotypic coefficient of variation, phenotypic coefficient of variation, heritability, and genetic advance (Allard, 1960; Johnson 1995; Falconer and Mackay, 1996).

Numerous scholars have reported the indicators of variability, heritability, and the advance of coriander genotypes in different countries (Singh et al., 2006; Mengesha and Alemaw, 2010; Ibrahim, et al., 2013; Awas et al., 2015; Farooq et al., 2017; Kassahun, 2018; Patel et al., 2018; Choudhary et al., 2021). Although Mengesha and Alemaw (2010), Awas et al. (2015), and Kassahun (2018) reported the presence of variability in Ethiopian coriander accessions, the current knowledge about its biology, variety development, and agronomic practices is neither complete nor conclusive. Therefore, it is necessary to study and generate information on variance components, heritability, and genetic advance. Thus, this study aimed to determine the extent of phenotypic and genotypic variation, heritability, and genetic advance of various yield and yield-related traits of coriander.

2. MATERIALS AND METHODS

2.1. Description of the study area

The research was conducted during the 2019 and 2020 (July to November 2019 and 2020) *meher* season at the Kulumsa Agricultural Research Center (KARC) under field conditions. It lies between 8° 00' and 8° 02'N and 39° 07' and 39° 10'E at an altitude of 2210 m.a.s.l. in Tiyo District Arsi Administrative Zone of Oromia Regional State, 167 km southeast of Addis Ababa. KARC is located on gentle terrain with slopes ranging from 0 to 10%. It has little variation in elevation ranging from 1,980 to 2,230 meters (Abayneh et al.2003). The agro-climatic conditions of the area are humid with an average annual rainfall of 832 mm and have an uneven rainfall regime with the rainy season lasting from March to September. However, the peak season is from July to August and the average annual minimum and maximum temperatures are 10°C and 23.20°C, respectively (KARC metrological station, unpublished data). The coldest month is December while March and May are the hottest months. KARC has three main types of soils; Eutric Vertisol, Vertic Luvisol and Vertic Cambisol (Abayneh et al. 2003).

2.2. Experimental materials and design

Twenty-three accessions were originally obtained from the Ethiopian Biodiversity Institute (EBI), and two released varieties representing crop germplasm were obtained from KARC (Table 1). The experiment was laid out in a 5×5 simple lattice design, with each genotype replicated twice.

Table 1: List of accessions evaluated for 8 morphological traits

Sl. No.	Treatment	Source	Remark	Sl. No.	Treatment	Source	Remark
1.	ACC-229714	EBI	Accession	14.	ACC-240577	EBI	Accession
2.	ACC-212115	EBI	Accession	15.	ACC-211568	EBI	Accession
3.	ACC-202734	EBI	Accession	16.	ACC-240552	EBI	Accession
4.	ACC-240546	EBI	Accession	17.	ACC-90309	EBI	Accession
5.	ACC-212830	EBI	Accession	18.	ACC-90451	EBI	Accession
6.	ACC-240574	EBI	Accession	19.	ACC-229716	EBI	Accession
7.	ACC-211471	EBI	Accession	20.	ACC-90444	EBI	Accession
8.	ACC-90305	EBI	Accession	21.	ACC-229811	EBI	Accession
9.	ACC-329702	EBI	Accession	22.	ACC-212950	EBI	Accession
10.	Indium 01	KARC	Variety	23.	ACC-202518	EBI	Accession
11.	ACC-212225	EBI	Accession	24.	Denkinesh	KARC	Variety
12.	ACC-240547	EBI	Accession	25.	ACC-X1	EBI	Accession
13.	ACC-20662	EBI	Accession			EBI	

EBI: Ethiopian Biodiversity Institute; KARC: Kulumsa Agricultural Research Center

The row length of a plot was 2.0 m and 2.4 m width with spacing of 40 cm between rows and 1m between plots. The four central rows were net plots in which, plant and plot base data recording was applied. The net plot size of each experimental unit was 2 m ×1.6m = 3.2 m^2.

2.3. *Data collection and statistical analysis*

Eight yield and yield-related traits were measured, including plant height (cm), number of umbels $plant^{-1}$, number of umbellets $umbel^{-1}$, number of seeds $umbel^{-1}$, number of seeds $umbellet^{-1}$, seed yield $plant^{-1}$ (g), thousand seed weight (g), and seed yield (t ha^{-1}). The data collected for each trait were subjected to analysis of variance (ANOVA) according to the method described in (Gomez and Gomez, 1984) using R software (Anonymous, 2020). Duncan Multiple Range Test was used to compare the mean performance of coriander accessions at a 5% level of significance.

Phenotypic and genotypic variances and coefficient of variations were computed following the formula suggested by Burton and De Vane (1953). According to Deshmukh et al. (1986) phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) values >20%, <10%, and between 10% and 20% were considered high, low, and intermediate, respectively. Heritability (H^2b) in a broad sense and expected genetic advance were estimated by the method suggested by Johnson (1995) and Allard (1960). As detailed by Pramoda and Gangaprasad (2007) generally heritability estimates were classified as low (<40%), medium (40-59%), moderately high (60-79%) and very high (≥80%) and genetic advance as percent of the mean as low (0-10%), moderate (10-20%), and high (>20%) (Johnson et al., 1955).

3. RESULTS AND DISCUSSION

3.1. *Analysis of variance, range and mean performance of accessions*

Homogeneity of error variances was assured through maximum F-ratio as a shortcut test for heterogeneity of error variance, as suggested by Hartley (1950). Combined data analysis was performed over the years, as the data were homogenous. The pooled analysis of variance showed that there was a highly significant ($P<0.01$) difference among the studied genotypes for plant height (cm), number of umbels $plant^{-1}$, number of umbellets $umbel^{-1}$, number of seeds $umbel^{-1}$ and umbellets, seed yield $plant^{-1}$ (g), 1000 seed weight (g) and seed yield (t ha^{-1}) (Table 2). This might provide an opportunity for the crop to be subjected to further selection and hybridization. According to Mengesha and Alemaw (2010), 49 Ethiopian coriander accessions showed considerable variance for the number of umbels $plant^{-1}$, umbellets $umbel^{-1}$, seeds $umbellets^{-1}$, 1000 seed weight (g), seed yield $plant^{-1}$, and seed yield (t ha^{-1}) but no significant variation in plant height. Similar to this, Singh et al. (2006) reported that there was low variability for umbellets $umbel^{-1}$ and significant variability for seed yield, umbel $plant^{-1}$, and seeds $umbel^{-1}$ among 360 lines of coriander. In line with current findings, 81 Ethiopian coriander genotypes differed significantly for all traits included in this experiment, with the exception of umbel number $plant^{-1}$ and number of seeds $umbellet^{-1}$ (Awas et al., 2015).

Seed yield ranged from 0.8 t ha^{-1} (ACC-240577) to 5.99 t ha^{-1} (ACC-240574), and plant height varied from 61.64 cm (ACC-20662) to 182 cm (ACC-229811). Awas et al. (2015) outlined seed yield in the range of 0.16 to 3.05 t ha^{-1}

Table 2: Combined mean squares of 8 quantitative traits of 25 coriander accessions tested at Kulumsa in 2019 and 2020

Traits	Replication (DF=1)	Block (Rep) (D=8)	Year (DF=1)	Source of variation				
				Acc (DF=24)	Year*Acc (DF=)	Error (DF=41)	CV (%)	R^2
PH	154.77	63.72	18455.96**	936.77**	37.25	47.84	6.14	0.95
UPP	134.33	14.21	4155.74**	513.06**	19.09**	7.35	5.36	0.98
ULTSPU	4.87	4.2	387.22**	33.14**	0.83**	1.16	11.47	0.94
SPU	12.11	16.97	8.44	90.9**	4.25	9.12	12.62	0.82
SPULTS	7.67	0.41	64.87**	1.48**	0.021	0.22	7.54	0.9
SYLDPP	24.21	6.29	234.28**	79.57**	2.19	5.32	17.02	0.89
TSW	8.3	2.18	43.91**	6.62**	0.137**	0.99	8.79	0.79
SYLDPHA	0.19	0.21	9.76**	5.39**	0.078	0.058	8.96	0.97

*: p=0.05; **: p=0.01; ns: non-significant difference; DF: Degrees of freedom; CV: Coefficient of variation; PH: Plant height at maturity (cm); UPP: Umbels plant^{-1}; ULTSPU: Umbellets umbel^{-1}; SPU: Seeds umbel^{-1}; SPULTS: Seeds umbellets^{-1}; SYPP: Seed yield plant^{-1} (g); TSW: thousand seed weight (g); SYPH: Seed yield (t ha^{-1})

(Table 4). Mengesha and Alemaw (2010) also reported seed yield in a range of 0.91 to 3.1 t ha$^{-1,}$ which is in line with the current study, and earlier research by Diederichesen (1996) also stated comparable findings. The weight of the thousand seeds of the tested accessions ranged from 8.68 g (ACC-240574) to 16.9 g (ACC-240552), which is in agreement with the previous studies of Arganosa et al. (1998) and Mengesha and Alemaw (2010). The accessions with the highest mean seed yield were Denkinesh (5.23 t ha^{-1}), followed by ACC-240574 (5.2 t ha^{-1}), ACC-202734 (5.04 t ha^{-1}), ACC-X1 (4.45 t ha^{-1}), and ACC-240546 (4.01 t ha^{-1}). Seventeen accessions outperformed the standard check Indium 01, with the first two accessions producing 101.55% and 95.35% yield advantages, respectively. The high-yielder accessions, however, demonstrated a yield advantage of more than 100% when compared with the standard check, Indium 01 (Table 3). Wide variations among the accessions for this trait may be seen in the variety of umbel numbers plant^{-1}, which ranged from 31.6 to 98.25 (Table 4). The highest mean umbel number plant^{-1} was obtained from ACC-240546 (85.1), followed by ACC-202518 (68.06) and ACC-240574 (67.73).

Singh et al. (2006) reported a low range of umbel number plant^{-1} (3.1–9) in Indian coriander accessions, while Awas et al. (2015) reported an umbel number ranging from 20.65–60.1, which is equivalent to the current results in Ethiopian coriander accessions. According to Bhandari and Gupta (1993), Indian coriander genotypes have 3.2–39.3 umbels plant^{-1}, which is a very small range when compared to Ethiopian coriander accessions reported earlier and the current research. Qureshi et al. (2009) reported an even greater range (121-336) for umbel number plant^{-1} in coriander genotypes examined in Pakistan.

The number of seeds per umbellet showed the highest variation among the accessions, with a range of 4.6-9.2 (Table 4). Mengesha and Alemaw (2010) reported a range of 5.25-9.30 for the number of seeds per umbellet, which is consistent with the present study. Awas et al. (2015) also reported a range of 5.5-10.8 for the number of seeds per umbellet in Ethiopian coriander accessions, further supporting the consistency of the present data (Table 4).

Significant variation among accessions was observed for plant height at maturity, ranging from 61.4 to 182 cm. ACC-X1 had the highest over-season mean plant height at maturity (155.28 cm), followed by ACC-212950 (143.62 cm), ACC-202734 (134.9 cm), and ACC-240547 had the lowest value (87.71 cm). The fertile soil and prolonged growth period may have contributed to this extreme height, which could result in yield losses from lodging and shattering. To mitigate this, it may be suggested to cross those accessions with dwarf types. Fikre et al. (2017) reported mean values for plant height from six areas in Ethiopia (Asosa, Kulumsa, Gonder, Sinana, Sirinka, and DebreZeit), with the Denkinesh cultivar having a height of 110.08 cm.

Mengesha and Alemaw (2010) and Awas et al. (2015) reported lower plant heights in coriander, with ranges of 38.8-92.8 cm at Kokate and Wondo Genet and 49.65-97.3 cm at Adami Tulu, respectively. The weight of a thousand seeds in the present study ranged from 8.68 to 16.9 g, with an overall mean of 12.52 g. Bhandari and Gupta (1993) and Parthasarathy et al. (2008) reported a comparable range of 5-22.1 g for coriander thousand seed weight. Mengesha and Alemaw (2010) reported a range of 9.8-12.8 g for coriander genotypes, while Awas et al. (2015) stated a wider range of 3.25-14.4 g. Mengesha and Alemaw (2010) and Awas et

Table 3: Mean performances of 25 coriander accessions for eight yield and yield related traits evaluated at Kulumsa in 2019 and 2020

Accessions	Traits							
	PH	UPP	ULTSPU	SPU	SPULTS	SYPP	TSW	SYPH
ACC-229714	110.1^{e-h}	52.65^{fg}	13.75^{b-e}	21.76^{ghi}	5.51^{i}	12.1^{e-h}	12.37^{c-f}	3.23^{fg}
ACC-212115	105.61^{ghi}	63^{cd}	11.79^{efg}	13.2^{j}	6.4^{e-h}	9.55^{g-j}	13.38^{bcd}	1.44^{i}
ACC-202734	134.9^{bc}	62.33^{cd}	13.97^{bcd}	26.73^{c-h}	7.41^{b}	16.2^{bcd}	12.09^{d-h}	5.04^{a}
ACC-240546	115.01^{d-g}	85.19^{a}	17.46^{a}	31.13^{bc}	7.16^{b-e}	28.79^{a}	11.44^{e-h}	4.01^{c}
ACC-212830	126.02^{cd}	65.1^{bc}	11.95^{d-g}	27.3^{c-g}	6.3^{e-i}	14.12^{cde}	13.1^{b-g}	3.48^{def}
ACC-240574	121.27^{de}	67.73^{b}	13.1^{c-f}	32.62^{b}	7.26^{bc}	19.55^{b}	11.3^{gh}	5.2^{a}
ACC-211471	119.83^{def}	53.55^{fg}	9.13^{ijk}	22.47^{fi}	6.3^{i-e}	13.62^{def}	12.1^{d-h}	3.94^{c}
ACC-90305	116.98^{d-g}	51.19^{g}	13.04^{c-f}	27.61^{b-f}	7.35^{bc}	14.07^{cde}	10.73^{h}	3.73^{cde}
ACC-329702	121.63^{de}	50.68^{g}	11.68^{e-h}	25.79^{c-h}	6.78^{b-h}	13.24^{d-g}	11.36^{fgh}	3.32^{ef}
INDIUM 01	102.93^{hij}	49.95^{g}	11.73^{e-h}	25.69^{c-h}	6.84^{b-h}	13.45^{d-g}	13.27^{b-e}	2.58^{h}
ACC-212225	116.3^{d-g}	42.53^{h}	9.95^{ghi}	29.3^{bcd}	5.92^{hi}	9.89^{f-j}	11.38^{fgh}	2.55^{h}
ACC-240547	87.71^{k}	41.29^{h}	7.34^{kl}	22.67^{f-i}	6.3^{e-i}	13.3^{e-j}	13.5^{bcd}	1.44^{i}
ACC-20662	94.27^{jk}	59.4^{de}	14.68^{bc}	23.07^{e-i}	6.84^{b-g}	18.46^{b}	11.92^{d-h}	3.02^{fg}
ACC-240577	108.74^{fgh}	52.31^{g}	9.61^{hij}	29.12^{bcd}	6.59^{b-h}	9.93^{f-j}	10.98^{h}	1.02^{i}
ACC-211568	106.95^{ghi}	38.03^{h}	6.29^{l}	20.05^{i}	4.88^{b-g}	8.17^{ij}	13.63^{d-h}	1.42^{i}
ACC-240552	96.78^{ijk}	42.41^{h}	7.73^{jkl}	25.59^{d-h}	6.21^{f-i}	11.84^{e-i}	15.62^{a}	3.15^{fg}
ACC-90309	97.11^{ijk}	61.03^{cde}	10.33^{ghi}	21.76^{ghi}	5.92^{hi}	13.7^{def}	14.68^{ab}	2.57^{h}
ACC-90451	108.47^{fgh}	63.68^{bcd}	10.27^{ghi}	22.77^{fi}	8.4^{a}	17.59^{bc}	11.91^{d-h}	2.49^{h}
ACC-229716	112.32^{e-h}	49.5^{g}	11.5^{fgh}	27.2^{c-g}	6.78^{b-h}	13.55^{def}	14.32^{ab}	2.84^{h}
ACC-90444	111.88^{e-h}	51.98^{g}	11.72^{e-h}	28.51^{b-e}	7.07^{b-f}	18.81^{b}	13.08^{b-g}	3.06^{fg}
ACC-229811	114.56^{d-g}	63.68^{bcd}	13.84^{b-e}	27.1^{c-g}	6.4^{e-h}	14.59^{cde}	13.21^{b-f}	3.9^{cd}
ACC-212950	143.62^{b}	38.38^{h}	7.25^{kl}	24.89^{d-i}	6.02^{ghi}	7.84^{j}	12.22^{d-h}	3.96^{c}
ACC-202518	132.37^{c}	68.06^{b}	15.65^{ab}	23.88^{d-i}	6.49^{ch}	14.58^{cde}	10.73^{h}	3.96^{c}
Denkinesh	112.14^{e-h}	56.93^{ef}	13.44^{c-f}	38.39^{a}	7.16^{b-e}	13.08^{d-g}	12.41^{c-h}	5.23^{a}
ACC- X1	155.28^{a}	39.38^{h}	7.09^{kl}	24.18^{d-i}	6.97^{b-f}	9.1^{hij}	14.15^{abc}	4.45^{b}
Mean	114.95	54.82	11.37	25.7	6.68	13.88	12.52	3.24

PH: Plant height at maturity (cm); UPP: Umbels plant^{-1}; ULTSPU: Umbellets umbel^{-1}; SPU: Seeds umbel^{-1}; SPULTS: Seeds umbellets^{-1}; SYPP: Seed yield plant^{-1} (g); TSW: Thousand seed weight (g); SYPH: Seed yield (t ha^{-1})

al. (2015) also outlined wider ranges of 7.83-32.85 g and 1.5-14.5 g, respectively, for coriander thousand seed weight.

3.2. Estimation of phenotypic and genotypic coefficient of variation

The estimated PCV and GCV of the eight traits of coriander accessions under study are presented in Table 4. For all traits, the estimated PCV was generally larger than the genotypic coefficient of variance in magnitude. In the 2019 crop year, seed yield t ha^{-1} had the highest phenotypic coefficient of variation (32.70%), followed by the seed yield plant^{-1} (30.03%), the number of umbellets plant^{-1} (24.77%), and the number of seeds umbellet^{-1} (20.03%). The PCV was intermediate for plant height (10.87%), umbel number plant^{-1} (17.98%), number of seeds umbellet^{-1} (12.32%), and thousand seed weight (11.60%). In the 2020 crop year, the highest PCV was estimated for seed yield plant^{-1} (33.07%), followed by seed yield t ha^{-1} (31.28%) and number of umbellets umbel^{-1} (25.86%) (Table 4). Similar findings were reported for coriander by Singh et al. (2006), Bhandari Gupta (1993), and Awas et al. (2015). In the present study, the estimated values of phenotypic variance (δ^2p) ranged from 0.53 for the number of seeds umbellet^{-1} to 2139.38 for the number of umbellets plant^{-1}. In the 2019 crop

Table 4: Estimate of range and variability components for eight yield and yield related traits of 25 coriander accessions tested at Kulumsa in 2019 and 2020

Traits	Range		δ^2e	δ^2g	δ^2p	GCV (%)	PCV (%)	H^2b (%)	GA	GAM (%)
	Min	Max								
2019										
PH	91.00	182.00	55.22	140.16	195.38	9.21	10.87	71.4	20.69	16.09
UPP	31.6	76.4	8.4	67.21	75.61	16.95	17.98	88.89	15.95	32.96
ULTSPU	13.34	7.67	1.95	8.87	10.92	22.45	24.77	82.14	5.6	9.14
SPU	13.01	38.20	13.4	12.50	25.90	13.91	20.03	48.25	5.07	19.94
SPULTS	4.60	7.80	0.32	0.21	0.53	7.70	12.32	39.05	0.58	9.93
SYPP	5.66	24.65	4.83	8.93	13.76	24.19	30.03	64.89	4.96	40.20
TSW	8.68	15.36	0.93	0.96	1.89	8.27	11.60	50.79	1.44	12.16
SYPH	0.80	5.09	0.036	0.88	0.92	32.05	32.70	96.08	1.20	64.82
2020										
PH	61.64	144.87	42.84	189.46	232.3	13.58	15.04	82.56	25.64	25.3
UPP	39.5	98.25	9.18	134.96	144.14	18.96	19.6	93.63	23.19	37.85
ULTSPU	4.06	14.51	0.97	4.95	5.91	23.65	25.86	83.67	4.2	6.85
SPU	13.21	38.77	8.52	18.63	27.15	16.61	20.05	68.6	7.37	28.38
SPULTS	6.29	9.2	0.22	0.21	0.44	6.15	8.83	48.59	0.66	8.85
SYPP	6.97	36.32	8.53	17.45	25.98	27.1	33.07	67.16	7.06	45.82
TSW	9.55	16.9	1.47	0.79	2.26	6.74	11.4	34.98	1.08	8.22
SYPH	0.97	5.99	0.09	1.14	1.24	30.11	31.28	92.64	2.12	59.78

PH: Plant height at maturity (cm); UPP: Umbels plant^{-1}; ULTSPU: Umbellets umbel^{-1}; SPU: Seeds umbel^{-1}; SPULTS: Seeds umbellets^{-1}; SYPP: Seed yield plant^{-1} (g); TSW: Thousand seed weight (g); SYPH: Seed yield (t ha^{-1}); σ^2g: Genotypic variance; σ^2p: Phenotypic variance; GCV: Genotypic coefficient of variation; PCV: Phenotypic coefficient of variation; H2b: Heritability in broad sense; GA: Expected genetic advance; GAM: Genetic advance as percentage of the mean

year, the highest genotypic coefficient of variation (GCV) was obtained for seed yield t ha^{-1} (32.05%), followed by seed yield plant^{-1} (24.19%), number of umbellets plant^{-1} (22.45%), and number of umbels plant^{-1} (16.95%). The GCV was lower for number of seeds umbellet^{-1} (7.7%), thousand seed weight (8.27%), and plant height (9.21%). The highest GCV values were estimated for seed yield (t ha^{-1}), seed yield plant^{-1} and number of umbellets umbel^{-1} in the 2020 crop year. Awas et al. (2015) reported higher GCV for plant height and seed yield per hectare, while Mengesha and Alemaw (2010) reported higher values for seed yield and seed number per plant in Ethiopian coriander genotypes. However, the genotypic coefficient of variation alone does not provide information on the heritability of variation. Therefore, GCV together with heritability estimates would give a better picture of the expected advance from selection (Burton and De Vane, 1953).

3.3. Estimates of heritability and genetic advance

The results presented in Table 4 indicated in the 2019 crop year, seed yield ha^{-1} (96.08%), number of umbels plant^{-1} (88.89%), and number of umbellets umbel^{-1} (82.14%) had the highest estimates of heritability in a broad sense (H^2b). In the 2020 crop year, high to very high estimates of H^2b were obtained for each trait, except, for thousand seed weight and number of seeds per umbellets.

These findings were consistent with the conclusions reached by Bhandari and Gupta (1993) regarding the broad sense heritability estimates for 200 coriander genotypes in India. However, Mengesha and Alemaw (2010) found very high and moderately high broad sense heritability estimates for seed yield per plant (83%) and seed yield per hectare (77%), respectively, in Ethiopian coriander landraces. In partial agreement with the present study, Awas et al. (2015) outlined moderately high and medium heritability estimates for plant height at maturity (66.9%) and seed yield per hectare (48.2%), respectively in 81 Ethiopian coriander accessions tested at Adami Tulu, Ethiopia. Therefore, phenotypic selection could work well with these features. The moderately high to high broad sense heritability estimates observed for most traits in this study suggest that phenotypic selection could be effective for improving these traits. Specifically, in 2019, moderately high heritability was observed for plant height (71.4%) and seed yield per plant (64.89%), while medium broad sense heritability values were observed for seed number per umbellet (48.25%) and thousand seed weight (50.79%). However, the number of seeds per umbellet (39.05) in 2019 had low heritability values in the broad sense, indicating limited potential for improvement through selection.

In the 2019 and 2020 crop years, the expected genetic advances as a percentage of the mean (GAM (%)) for selecting at 5% selection intensity of the accessions fluctuated between 9.14% to 64.82 and 6.85 to 59.78 for the number of umbellets per umbel and seed yield t ha-1, respectively (Table 4). The highest GAM (%) were observed for number of umbellets per umbel (32.96%), seed yield per plant (40.2%), and seed yield per hectare (64.82%) in this study. In contrast, low genetic advances were observed for number of seeds per umbellet and number of umbellets per plant in 2019 (Table 4). In 2020, there were GAM (%) in traits such as umbel number per plant (37.85%), plant height (25.3%), number of umbellets per umbel (28.38%), seed yield per plant (45.82%), and seed yield ha^{-1} (59.78%), but the genetic advances as a percentage of the mean for the remaining three traits were lower (Table 4). The expected genetic gain, expressed as a percentage of the mean, for choosing the top 5% of genotypes ranged from 9.14% to 64.82% and 6.85% to 59.78% in the 2019 and 2020 crop years, respectively (Table 4). These findings suggest that selecting genotypes based on these traits with high GAM (%) could lead to a substantial increase in yield under similar circumstances. Consistent with the current study, Awas et al. (2015) reported high GAM (%) for seed yield per hectare in 81 Ethiopian coriander germplasms, while Mengesha and Alemaw (2010) and Singh et al. (2006) found high genetic advances for seed yield $plant^{-1}$, seed yield ha^{-1}, and umbels $plant^{-1}$, consistent with the present results.

In this study, seed yield ha^{-1}, number of umbellets $plant^{-1}$, number of umbels $plant^{-1}$, seed yield $plant^{-1}$ and plant height had high to very high heritability values combined with moderate to high genetic advances as a percentage of the means. Johnson et al. (1955) suggested that while high heritability does not always lead to high genetic gain, heritability estimates and genetic advances should be considered together. When combined with genetic advances expressed as a percentage of the mean, heritability estimates become more informative (Johnson et al., 1955; Allard, 1960). Additionally, according to Panse (1957), the link between high heritability and high genetic gain is due to the additive gene effect. Therefore, selection based on these traits could lead to improved progeny performance.

4. CONCLUSION

There was a wide range of variability among the Ethiopian coriander accessions tested. Simultaneous improvements in yield and related traits can be attained through selection or hybridization, considering traits with high heritability coupled with high genetic advance as a percentage of the mean augment the progeny performance and productivity of coriander. The results had practical implications for breeders and farmers. Processing quality and diversity among Ethiopian coriander accessions need to be assessed in the future.

5. ACKNOWLEDGMENT

Authors would like to gratefully acknowledge the financial support provided by Ethiopian Institute of Agricultural Research and Kulumsa Agricultural Research Center to conduct the present study.

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