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Production of New Populations in Coriander (*Coriandrum sativum* L.) to Improve Foliage Traits

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ABSTRACT

This study aimed to develop new populations of *Coriandrum sativum* L. with an increased number of basal leaves. The research focused on crossing two distinct coriander varieties: 'UNAPAL Laurena', which typically produces 4–5 basal leaves plant^{-1}, and 'Slow bolt', renowned for its prolific production of 25–30 basal leaves plant–1. The goal of this crossing strategy was to combine the desirable traits of both varieties—leveraging the adaptability of 'UNAPAL Laurena' and the high foliage yield of 'Slow bolt'—to develop new populations with superior agronomic characteristics. The initial cross yielded an F1 population consisting of 35 families. These F1 plants were isolated and self-pollinated to produce the F2 population. Within the F2 population, individual plants were selected to form 25 families, which were then characterized using 13 quantitative morphological descriptors. Analysis of variance and Duncan's multiple range test were applied to evaluate intra- and inter-family variability. The results revealed significant differences, enabling the selection of superior families. These selected families were subsequently isolated in the field to establish the F3 generation. Morphological characterization of the F3 population showed a genetic gain, with an average increase of 10.4 basal leaves plant^{-1}. This outcome highlights the potential for developing new coriander populations with enhanced leaf yield, thereby improving overall production efficiency.

Introduction

Coriander (*Coriandrum sativum* L.), a member of the Apiaceae family, is a widely cultivated herb valued for its culinary versatility and aromatic qualities. It holds significant economic and cultural importance across various regions (Scandar et al., 2023). Enhancing the genetic composition of coriander breeding populations is crucial for improving agronomic performance, optimizing desirable traits, and increasing productivity (Gholizadeh et al., 2018). This study explores genetic strategies to advance coriander breeding populations, emphasizing morphological characterization, trait evaluation, and the integration of conventional and participatory plant breeding approaches. Variability within breeding populations is fundamental to the success of systematic crop improvement programs (Das et al., 2023). In coriander, understanding genetic and non-genetic variability is essential for selecting desirable traits and developing effective breeding strategies tailored to diverse environmental conditions and stakeholder needs (Chandrakala et al., 2023). Recent advancements in next-

generation sequencing technologies have revolutionized plant breeding, offering powerful tools for rapid genetic improvement (Ray and Satya, 2014; Satam et al., 2023). These technologies enable the identification of quantitative trait loci (QTL), marker-assisted selection, and the pyramiding of desirable genes (Kayihan et al., 2023), significantly enhancing breeding efficiency and precision. Integrating modern technologies with traditional breeding methods and participatory approaches ensures that breeding programs remain scientifically robust and practically relevant to smallholder farmers and other stakeholders (Ashraf et al., 2022). By addressing the unique challenges of diverse agro-ecological zones, coriander breeding programs can develop resilient, high-yielding varieties tailored to community-specific needs (Chandrakala et al., 2023). This study focused on improving basal leaf production, a critical trait for increasing leaf yield and overall productivity. Two coriander varieties were crossed: 'UNAPAL Laurena', known for its adaptability and production of 4–5 basal leaves plant^{-1}, and 'Slow bolt', recognized for its prolific 25–30 basal leaves plant^{-1}. The goal was to combine the adaptability of 'UNAPAL Laurena' with the superior foliage yield of 'Slow bolt' to develop populations with enhanced agronomic traits. The initial cross produced 35 families in the F1 generation, which were isolated and self-pollinated to generate the F2 generation. From this population, 25 families were selected and characterized using 13 quantitative morphological descriptors to identify promising trait combinations. This research highlights the importance of genetic variability and advanced breeding techniques in coriander improvement. By blending traditional methodologies with modern innovations, this study contributes to developing superior coriander varieties, with enhanced agronomic traits and increased yield, while addressing the diverse needs of producers and consumers.

Material and methods

Study area

This research was conducted at the Experimental Centre of the National University of Colombia, Palmira Campus (CEUNP), located in the municipality of Candelaria, Valle del Cauca, Colombia. The study site is situated at geographical coordinates 3°25'34.41"N latitude and 76°25'51.09"W longitude, at an altitude of 1050 meters above sea level. The region experiences an average temperature of 25 °C, relative humidity of 76%, and annual rainfall of approximately 1100 mm, creating a favorable environment for coriander cultivation. The soils at CEUNP are primarily clay and loam in texture, offering optimal water retention and nutrient availability—key factors for robust coriander growth. This setting provides a representative agricultural environment to evaluate the genetic improvement of coriander, enabling the assessment of plant performance under realistic agronomic conditions. The combination of favorable climatic conditions, including consistent temperatures and adequate rainfall, along with suitable soil properties, supports vigorous plant growth and thorough evaluation of morphological and agronomic traits. The study's location ensures the relevance and applicability of its findings to similar agro-ecological zones, offering valuable insights into coriander breeding strategies and their potential impact on agricultural productivity.

Plant materials

The genotypes of coriander in this study exhibited distinct agronomic traits. 'UNAPAL Laurena' is distinguished by its erect growth habit and trifoliate basal leaves. The stems are green and aristate, with the plant reaching the flowering stage in 36-40 d and becomes ready for harvest in approximately 35 d. The 'UNAPAL Laurena' genotype typically produces four to five basal leaves. The experimental yield is 65 $\pm$ 5 t ha^{-1}, while the commercial yield is 40 $\pm$ 5 t ha^{-1}. The sowing density ranges from 1,600,000 to 2,000,000 plants ha^{-1}. This variety is well adapted to the geographical and agro-climatic conditions of the Valley of the Cauca River and the coffee-growing areas, making it a suitable choice for cultivation in these specific environments.

'Slow bolt' is a cultivar that exhibits a relatively slow growth rate. It is distinguished by a medium to low growth rate and an intense green color. The lower leaves are stalked, while the upper leaves are bitripinnate. The 'Slow bolt' is typically harvested 60 d after sowing, having produced 25-30 basal leaves. The recommended seeding rate is 50-60 pounds ha^{-1}, with yields typically ranging from 20 to 25 t ha^{-1}. As an imported variety, 'Slow bolt' has been adapted to the cooler climates of Colombia's Altiplano Cundiboyacense. However, there are challenges for its production in warmer climates. These two genotypes were selected based on their contrasting morphological and agronomic traits, thereby providing a robust basis for assessing the potential for genetic improvement. The experimental phases of the study and the methods used to establish the coriander crop under field conditions appear in Table 1.

Table 1. Experimental phases and stages for the plant population study.

Phase	Stage	Description	Area (m^2)	Trays/Beds	Sowing distance	Tools/Materials	Purpose/Objective
I	1	Creation of seedbeds for 'Slow bolt' and 'UNAPAL Laurena' varieties.	N/A	4 trays each	N/A	72-cavity trays, black peat	Establish initial seedling growth
	2	Field establishment of 'UNAPAL Laurena' (staggered in greenhouse) and 'Slow bolt' (under black polythene).	36.3 ('UNAPAL'); 14.7 ('Slow bolt')	4 beds ('UNAPAL'); 5 beds ('Slow bolt')	25 cm	Greenhouse, black polythene, medicinal herb plot	Manage environmental conditions and establish seedlings in the field
	3	Agronomic management, floral evaluation, and isolation of umbels.	N/A	N/A	N/A	Terlenka tulle (<1mm pore), hand-held magnifying glass, 110 mm dissecting scissors, evaluation criteria (Table 2)	Isolate and evaluate flowers for seed production and emasculation timing
	4	Selection and emasculation of superior plants, cross-breeding to obtain F1 population.	N/A	N/A	N/A	115 mm fine-tipped dissecting forceps, hand-held magnifying glass	Cross varieties to obtain F1 population
II	1	Sowing of F1 population seeds in seedbeds	N/A	1 Tray	N/A	72-cavity tray, black peat	Initiate F1 population seedling growth
	2	Field sowing of F1 seedlings under polyshelter	9.1	N/A	40 cm	Polyshelter, medicinal herb plot	Control environmental conditions and establish F1 seedlings in the field
	3	Bringing F1 plants to flowering, isolation for self-fertilization to obtain F2 population.	N/A	N/A	N/A	Terlenka tulle enclosures (1.20 m high, 40 cm wide), fan	Ensure controlled self-fertilization and obtain F2 population
III	1	Planting F2 population and 'UNAPAL Laurena' in seedbeds	N/A	29 trays	N/A	72-cavity trays, black peat	Establish F2 population seedling growth
	2	Field transplantation of 27 F2 families, exposure to average climatic conditions	400	5 beds	40 cm	Cultivation field, randomized experimental design	Establish and quantify effects on F2 families
	3	Morphological characterization	N/A	N/A	N/A	Plant height, total biomass,	Evaluate morphological traits

		of F2 families and 'UNAPAL Laurena'			aerial part biomass, root biomass, stem biomass, stem diameter, leaf biomass, etc.	of F2 families
	4	Statistical analysis to identify superior families for basal leaf number trait	N/A	N/A	N/A	Measures of central tendency, dispersion, variance analysis, Duncan's clustering test	Identify significant differences and genetic gain in F2 families
	5	Isolation of selected F2 families and bringing to flowering stage	N/A	N/A	N/A	Terlenka tulle enclosures (2.8 m long, 1.40 m high, 0.5 m deep)	Control cross-breedng and maintain F3 population

Note: N/A = Not applicable; 'UNAPAL' = Universidad Nacional de Colombia campus Palmira.

Table 1. Continuation.

Phase	Stage	Description	Area (m^2)	Trays/Beds	Sowing distance	Tools/Materials	Purpose/Objective
IV	1	Sowing F3 population in seedbeds for subsequent field transplantation	N/A	N/A	N/A	72-cavity trays, black peat	Establish F3 population seedling growth
	2	Morphological characterization of F3 families	27.2	3 beds	35 cm	Central tendency, dispersion, variance analysis, Duncan's test.	Evaluate and analyze morphological traits of F3 families

Note: N/A = Not applicable; 'UNAPAL' = Universidad Nacional de Colombia campus Palmira.

This encompasses procedures for the evaluation of plant population dynamics and the genetic improvement of resulting populations, thereby ensuring a comprehensive approach to the understanding and improvement of coriander yield and productivity (Table 2).

Table 2. Evaluation of the phenotypic characteristics in the F2 and F3 populations of coriander.

Plant Variables	Unit of measurement	Agronomic traits
Plant height	cm	Stem with presence of inflorescence without basal leaves, axillary shoots
Total plant biomass	g	Weight of root, stem and foliage quantified
Mass of aerial part	g	Stem and leaf weight quantified
Stem biomass	g	Stem weight quantified
Root biomass	g	Root weight quantified
Foliage biomass	g	The difference between the weight of the aerial part and the fresh weight of the stem was measured.
Number of basal leaves	N.A.	The leaves attached to the base of the stem were separated and quantified.
Number of non-basal leaves	N.A.	The non-basal leaves were separated from the stem and counted.
Stem diameter	mm	Stem diameter measured
Number of nodes	N.A.	Quantification of the number of nodes present on the stem.
Total leaves of the plant	N.A.	Sum of the number of basal leaves and the number of non-basal leaves.
Length of longest basal leaf	cm	The longest basal leaf was measured.
Earliness	d	The number of days from germination to the appearance of the flowering stem was quantified

Note: N.A.= Not applicable.

Variable analysis

A detailed phenotypic analysis was conducted in both the F2 and F3 generations. Four representative plants were selected from each family to ensure a thorough evaluation. The analysis focused on the variables listed in Table 2, providing a robust examination of genetic and morphological characteristics relevant to the study's objectives. This systematic approach allowed for the identification of key traits influencing coriander yield and adaptability. The findings contributed to a deeper understanding of genetic variability, highlighting traits with significant potential for breeding improvements and advancing coriander cultivation strategies.

Data analysis

The selected phenotypic variables were subjected to rigorous statistical analysis to assess differences and variability within and between coriander populations. This analysis involved calculating means, coefficients of variation, and standard deviations to quantify central tendencies and data dispersion. Analysis of variance (ANOVA) was employed to identify significant differences between populations, while Duncan's multiple range test determined statistically significant groupings and further elucidated these differences. All data analyses were conducted using SAS software, version 9.4, ensuring robust and reliable statistical processing. This comprehensive approach provided critical insights into the genetic and phenotypic diversity of coriander populations, supporting informed selection and breeding decisions to enhance crop yield and performance.

Results

Evaluation of flowering

To optimize the likelihood of successful fertilization, emasculation of open flowers from all sub-umbels with white anthers was determined to be the most effective approach. This stage was chosen because the stigmas are receptive, maximizing the probability of successful pollination by pollen from the maternal plant. The results of crosses between the two varieties, 'UNAPAL Laurena' and 'Slow bolt', revealed a significant discrepancy in efficacy. Crosses with 'UNAPAL Laurena' as the maternal parent achieved a notably higher success rate of 42.85%, highlighting a strong maternal effect as a critical factor influencing crossbreeding success. In contrast, using 'Slow bolt' as the female parent was entirely ineffective, with no successful fertilizations observed. These findings underscore the importance of selecting the appropriate parental variety in breeding programs. The challenges associated with using 'Slow bolt' as a female parent suggest the need for further investigation into the genetic or physiological factors contributing to its reduced efficacy. Understanding these factors is essential to refining crossbreeding strategies and improving hybridization success rates in coriander breeding (Table 3).

Table 3. Evaluation of the efficacy of cross-breeding and seed production of coriander varieties.

Plant crossbreeding	Cross-breeding occasions carried out	Effective crossbreeding	Cross-breeding effectiveness (%)	Number of seeds obtained
Mother: 'UNAPAL Laureana'; Father: 'Slow bolt'	35	15	42.85	35
Mother: 'Slow bolt'; Father: 'UNAPAL Laureana'	12	0	0	0

A total of 35 seeds were successfully obtained from the maternal parent, 'UNAPAL Laurena', forming the initial F1 population. Due to the limited number of seeds and the uncertain success of the cross, all 35 seeds were sown to propagate and establish the F2 population. During the establishment of the F1 generation, eight plants exhibited stress symptoms and ultimately died, likely influenced by the 'Slow bolt' variety and prevailing climatic conditions. As a result, the remaining 27 plants were subjected to controlled self-fertilization, facilitated by wind currents generated by a fan to ensure effective pollination (Table 3). The seedlings derived from these 27 plants were then transplanted into the field to establish the F2 population. The planting followed a completely randomized design with three replications. Each of the 27 plants represented a distinct family, and 55 seeds were sown per family. Germination results for these plants appear in Figure 1, offering a comprehensive overview of the establishment and growth of the F2 population.

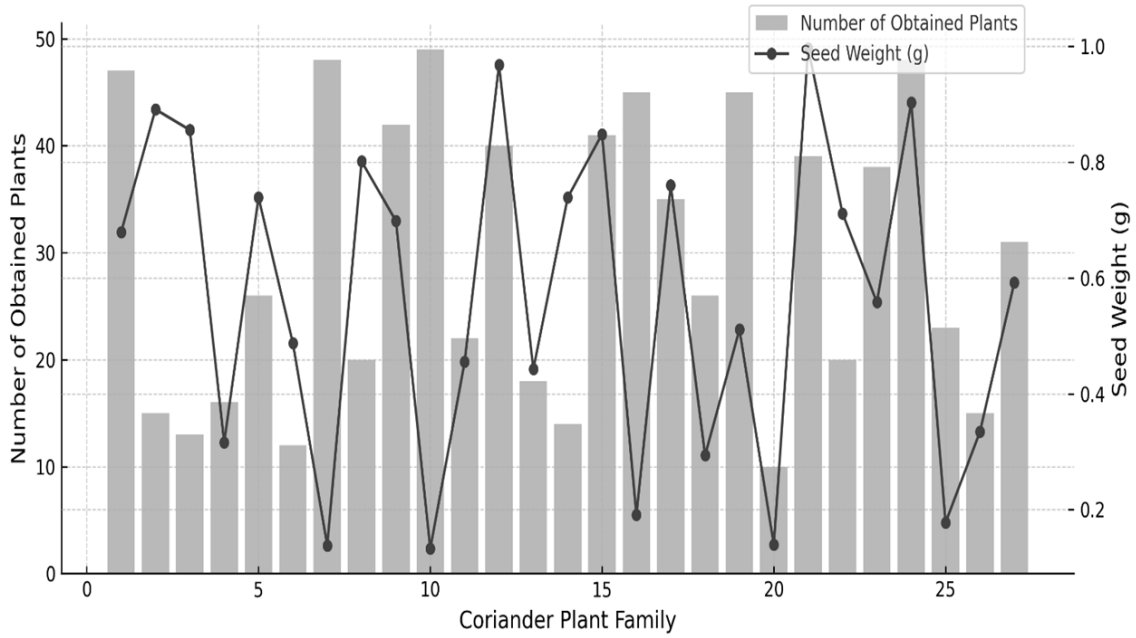

Fig. 1. Number of obtained plants and seed weight per coriander plant family.

It should be noted that the seedlings derived from the 27 plants were transferred to the field to constitute the F2 generation. This planting was conducted in a completely randomized design with three replicates. Each of the 27 plants resulted in the formation of distinct families, with 55 seeds sown for each family. The germination outcomes for these plants are presented herewith, offering an overview of the establishment and growth of the F2 population.

Morphological characterization of population F2

Table 4 presents the results of the analysis of variance (ANOVA) for the characteristics evaluated in the various coriander families. The results of the analysis of variance (ANOVA) demonstrate statistically significant differences between the evaluated families and in comparison, with the control variety, 'UNAPAL Laurena'. This indicates the presence of considerable genetic diversity within the breeding population.

Table 4. Mean squares for plant families evaluated population F2.

Source of variation	PH	TPM	APM	RM	SM	SD	FM	NBL	NN	NBL	TPL	LLBL	EA
Family	1039.93**	2966.62**	30.16**	2468.77**	142.61**	0.04**	1588.20**	78.88**	13.21*	141.05**	209.96**	221.30**	1039.93**
Error	300.15	567.14	7.86	467.45	33.73	0.009	291.22	13.2	5.73	48.97	61.86	40.81	300.15
CV	30.24	33.75	35.68	34.48	34.18	14.04	37.34	33.99	23.91	30.86	23.57	26.59	30.24
Mean	57.29	67.69	7.86	62.69	16.99	0.68	45.7	10.69	10.01	22.67	33.36	24.02	57.29
Deviation	17.32	23.81	2.80	21.62	5.80	0.09	17.06	3.63	2.39	6.99	7.86	6.38	17.32

Note: **Highly significant differences, *Significant difference ($P < 0.05$). CV: Coefficient of variation, PH: Plant height, TPM: Total plant biomass, APM: Aerial part biomass, RM: Root biomass, SM: Stem biomass, SD: Stem diameter, FM: Foliage biomass, NBL: Number of basal leaves, NN: Number of nodes, NNBL: Number of non-basal leaves, TPL: Total plant leaves, LLBL: Length of the longest basal leaf, EA: Earliness.

The observed discrepancies in these traits highlight the effectiveness of the breeding program in producing a diverse genetic pool. As shown in Table 4, this genetic diversity is

essential for selecting superior genotypes with desirable agronomic traits, ultimately improving the quality of coriander breeding populations. Significant differences were recorded in various morphological traits, including plant height, total biomass, root biomass, aerial biomass, stem biomass, stem diameter, leaf biomass, the number of basal and non-basal leaves, the total number of leaves, and the length of the longest basal leaf. Additionally, a marked variation was noted in the number of nodes (Fig. 2). A detailed assessment of morphological characteristics was performed on the germinated plants from 25 families. The evaluated traits included plant height (PH), total plant biomass (TPM), aerial part biomass (APM), root biomass (RM), stem biomass (SM), stem diameter (SD), foliage biomass (FM), number of basal leaves (NBL), number of nodes (NN), number of non-basal leaves (NNBL), total number of leaves (TPL), length of the longest basal leaf (LLBL), and earliness (EA).

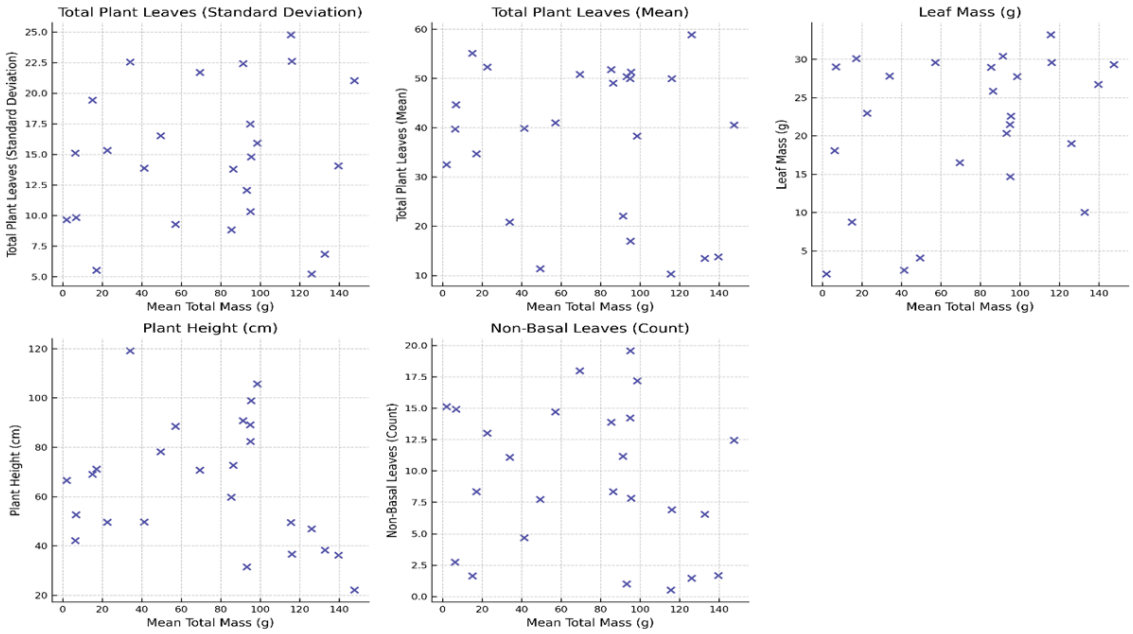

Fig. 2. Morphological traits among 27 coriander plant families in the F2 generation. Significant variations were observed in several traits, including plant height, total biomass, aerial biomass, stem biomass, stem diameter, leaf biomass, number of basal leaves, number of non-basal leaves, total number of leaves, and the length of the longest basal leaf. Furthermore, notable differences were identified in the number of nodes. To stabilize this trait for future breeding efforts, it is recommended that families with a high number of basal leaves, despite their variability, be selected individually.

With a coefficient of variation of 33.99% for basal leaf number, identifying families with a high mean basal leaf number and low variation is crucial for stabilizing this trait. Table 4 evaluates the F2 population, showing that families with both high basal leaf numbers and high variability can be targeted for individual selection to achieve trait stabilization (Fig. 2). Figure 2 also depicts the mean values for plant height, highlighting that family 18 diverges notably from 'UNAPAL Laurena' and other families, with a coefficient of variation of 35.5%, reflecting pronounced internal variability. A comparison of families 2, 8, 23, 10, 7, and 21—characterized by low variability and coefficients of variation between 3% and 10%—with family 18 and 'UNAPAL Laurena', which have a coefficient of variation of 16.01%, indicates superior trait expression in the former. Families 14, 15, and 19, on the other hand, exhibit a coefficient of variation of 51.63%, denoting high variability that complicates trait fixation. Regarding total biomass (Fig. 2), family 27 stands out with the highest total biomass, significantly differing from other families. However, its considerable height suggests a higher stem proportion relative to foliage, paired with a coefficient of variation of 44.19%, signifying high internal variability and challenging trait stabilization. Conversely, families 24, 26, 2, 15, 23, and 25 demonstrate higher average biomass compared to 'UNAPAL Laurena' and other families, with coefficients of variation ranging from 5.8% to 22.01%, identifying them as promising populations for

this trait. An analysis of the leaf proportion within plant structures for these families is essential. Family 18, with an average height of 104.25 cm and a total biomass of 64 g, exemplifies that greater height does not necessarily correlate with greater biomass, emphasizing the importance of evaluating both traits independently.

The comparative plots for the traits evaluated in the new F2 populations, as illustrated in Figure 2 (total leaves vs. total plant biomass; plant height vs. total biomass; non-basal leaves vs. total plant biomass), reveal no consistent correlation between plant height and the total number of leaves. For instance, Family 18, with an average height of 104.25 cm, 13.75 basal leaves, and 28.50 total leaves, appears more advanced than 'UNAPAL Laurena', which has an average height of 60.24 cm, 4.70 basal leaves, and 24.40 total leaves. However, when compared to Family 9, which has a height of 34.60 cm, a total biomass of 50.00 g, 14.75 basal leaves, and 33.25 total leaves, Family 9 demonstrates superior trait expression and a low growth habit, which is advantageous. A comparison of plant height and total plant biomass further shows that an increase in height does not necessarily correspond to an increase in biomass, suggesting an inverse relationship between these variables. "Total biomass" refers to the combined weight of the stem, root system, and foliage. Family 27, with a total biomass of 118.5 g, a height of 73.45 cm, approximately 5.2 basal leaves, and 33.5 total leaves, exhibits a higher proportion of stem relative to leaves. This indicates that an increase in height is often associated with greater stem biomass rather than an expansion in leaf number.

Morphological characterization of F3 populations

Table 4 presents the mean square results from the analysis of variance for the evaluated traits in the selected families. Significant differences were observed in plant height, total biomass, root biomass, number of basal leaves, number of non-basal leaves, total leaves, length of the longest basal leaf, and number of nodes. Additionally, significant block differences were detected for total biomass, root biomass, leaf biomass, number of non-basal leaves, total leaves, length of the longest basal leaf, and aerial part biomass. The variability was highest for total biomass, root biomass, aerial part biomass, stem biomass, and foliage biomass. For the number of basal leaves, the coefficient of variation was 18.35%, with a mean of 15.85 leaves and a standard deviation of 2.9 leaves. This relatively low variation indicates that the selected families exhibit uniform behavior, suggesting that this trait can be stabilized and consistently expressed.

Discussion

The results of this study underscore the substantial potential for refining and improving desirable traits within coriander breeding programs. By focusing on families with favorable averages and manageable variation, breeders can drive genetic advancements to optimize both yield and quality. These findings align with previous studies conducted in Iran (Khakshour et al., 2024) and Portugal (Farinha et al., 2023; Póvoa et al., 2024), which emphasized the importance of selecting genetically diverse and stable populations to achieve superior agronomic traits, even for agro-industrial applications. The identification of promising families in this study provides a strong foundation for future breeding efforts aimed at developing high-yielding coriander varieties with enhanced agronomic performance and resilience. The observed segregation within families (Figs. 1 and 2) validates the effectiveness of the crossbreeding approach, highlighting the importance of intra- and interfamilial variation for individual selection processes essential for improving specific traits. These findings are consistent with research conducted in India by Choudhary et al. (2022) and Gauhar et al. (2018), which underscored the role of genetic diversity analysis in identifying diverse genotypes and grouping similar genotypes for target traits. In this Colombian study, most of the new populations demonstrated superior expression of leaf traits compared to the two coriander varieties evaluated, 'UNAPAL Laurena' and 'Slow bolt'. Notably, 'UNAPAL Laurena' outperformed 'Slow bolt' in the number of basal leaves, highlighting the potential for improved trait expression through targeted breeding strategies. Consistent with the genetic improvement criteria outlined by Shiwangi et al. (2020), family 26 (Fig. 1) exhibited a unique profile, characterized by reduced basal leaves, total biomass, and height, but increased foliage and stem biomass. This family merits further evaluation to determine if the proportion of leaves and total biomass can be enhanced in subsequent generations, ensuring the development of robust coriander varieties with optimized agronomic traits. The crossbreeding approach employed in this study resulted in significant genetic variation within the F2 population (Table 4), contributing to the observed phenotypic diversity. This genetic segregation generated a broad range of trait expression, as reflected in the high coefficient of

variation (CV) values reported. These elevated CV values were indicative of the inherent variability in measured traits, influenced by a combination of biological diversity, environmental factors, and experimental conditions. Such variability is a critical component of the breeding program, providing valuable insights into the range of trait expression within the studied populations. This dynamic genetic material underscores the potential for selecting superior traits in future breeding efforts, ultimately contributing to the success and sustainability of coriander breeding programs.

The significant differences observed in various traits, such as plant height, total biomass, root biomass, and the number of basal and non-basal leaves, highlight the genetic diversity achieved through the breeding program (Table 4). This diversity is crucial for selecting superior genotypes with desirable agronomic traits, ultimately enhancing coriander breeding populations. Families such as 2, 8, 23, 10, 7, and 21, which exhibit low variability and favorable trait expression, are particularly promising for stabilizing and improving these traits. In contrast, families 14, 15, and 19, with high coefficients of variation, present challenges for trait fixation due to their significant internal variability (Fig. 2). This intra- and inter-family variation is essential for implementing effective individual selection processes, facilitating the genetic improvement of coriander. The ability to identify and target families with both high mean trait values and low variation aligns with previous research, which underscores the importance of selecting genetically stable families for breeding purposes. For instance, Boomer (2023) emphasized the role of genetic stability in improving crop yields and trait expression. Additionally, Krug et al. (2023) highlighted the importance of managing genetic diversity to prevent inbreeding depression and maintain robust plant populations. By harnessing this genetic diversity, breeders can make substantial progress in optimizing both yield and quality traits in coriander, ensuring the development of robust, high-performing varieties.

Conclusions

The identification of families exhibiting superior trait expression and manageable variability provides a strong foundation for ongoing coriander breeding efforts. The observed genetic diversity and significant differences in traits underscore the effectiveness of the crossbreeding program. Future efforts should focus on the continued evaluation and selection of these families to ensure the stabilization and improvement of desirable traits, ultimately leading to the development of enhanced coriander varieties. The results validate the success of the crossbreeding strategy, as demonstrated by the observed segregation within the populations. This segregation highlights the presence of crucial genetic diversity, which is essential for the effective implementation of a selection process. The families were ranked based on the means and coefficients of variation for key variables, including plant height, total biomass, the number of basal leaves, and the total number of leaves. This ranking system aids in identifying families with superior genetic traits, facilitating the selection of candidates for further breeding. The recombination between the selected parent varieties was effective, as reflected in the phenotypic variability observed within each family. This variability indicates the offspring are a hybrid population, resulting from the crossing of two distinct varieties. The newly generated populations showed improved performance in the trait of interest, namely the number of basal leaves, which translates to an increased leaf yield and, subsequently, a higher crop yield. In conclusion, these findings confirm the validity of the breeding program's approach and provide a clear pathway for further genetic improvement of coriander, ensuring the development of robust, high-yielding varieties.

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Author Contributions

Conceptualization, KALV and MAGD; methodology, KALV, LFCB, VLM, AZV and MAGD; software, KALV and MAGD; validation, KALV, LFCB, VLM, AZV and MAGD; formal analysis, KALV, LFCB, VLM, AZV and MAGD; investigation, KALV, LFCB, VLM, AZV and MAGD; resources, KALV and MAGD; data curation, KALV and MAGD; writing—original draft preparation, KALV and MAGD; writing—review and editing, KALV, LFCB, VLM, AZV and MAGD; visualization, KALV; supervision, KALV and MAGD; project administration, KALV and MAGD; funding acquisition, KALV and MAGD. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors indicate no conflict of interest in this work.

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