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Evaluation of selected seed spice varieties under rainfed regions of the semi-arid northern Telangana zone

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Abstract
A field study was conducted over two consecutive Rabi seasons (2023-24 and 2024-25) at the Horticultural Research Station, Adilabad, Telangana, to evaluate the performance of selected varieties of four important seed spices, Coriander (*Coriandrum sativum* L.), Cumin (*Cuminum cyminum* L.), Fenugreek (*Trigonella foenum-graecum* L.), and Ajwain (*Trachyspermum ammi* L.) under semi-arid agro-climatic conditions. The experiment was laid out in a randomized complete block design (RCBD) with four replications. Significant genotypic differences were observed for growth, phenological traits, reproductive parameters, and seed yield across all seed spice crops. In coriander, ACR-1 recorded the highest pooled seed yield (1827.08 kg/ha), attributed to greater umbels per plant, higher seed number per umbel, and superior 1000-seed weight. In cumin, GC-4 emerged as the best performer with a seed yield of 706.66 kg/ha, showing early flowering, vigorous branching, and bold seeds. Among fenugreek genotypes, AFG-1 was the most productive (1729.99 kg/ha), supported by its enhanced pod number, longer pods, and higher seed weight. In ajwain, AA-93 out- yielded other entries with 1133.33 kg/ha, benefiting from earliness, greater number of umbels, and seed boldness. The superior performance of these varieties was consistent across seasons, indicating strong adaptability and stability under the semi-arid conditions of Telangana. Genotype × environment interaction was evident, highlighting the importance of site-specific varietal selection. The findings suggest that ACR-1 (coriander), GC-4 (cumin), AFG-1 (fenugreek), and AA-93 (ajwain) are promising cultivars for commercial cultivation in semi-arid regions, offering improved productivity and resilience. Adoption of these improved genotypes can enhance income security for farmers and contribute to the sustainable intensification of spice-based cropping systems in Telangana and similar agro-ecological zones.

Keywords: Ajwain, coriander, cumin, fenugreek**,** growth and yield parameters**,** genotype × environment interaction

1. Introduction
Seed spices are a vital part of India's agricultural landscape, contributing to both domestic use and exports. While Rajasthan and Gujarat dominate seed spice production, Telangana is emerging as a potential contributor, particularly under semi-arid, rainfed conditions. Key seed spices being promoted in the region include coriander (*Coriandrum sativum* L), ajwain (*Trachyspermum ammi* L), cumin (*Cuminum cyminum* L), and fenugreek (*Trigonella foenum-graecum* L), valued for their agronomic and medicinal attributes. Seed spices offer a viable alternative to traditional Rabi crops like chickpea and maize, especially in Adilabad district. These crops require fewer inputs and offer higher profitability. However, limited awareness, lack of quality seed, and poor adoption of improved agronomic practices hinder productivity (Gondalia, 2019) [10]. Seed spices play a significant dietary and economic role in the state. A joint survey by PJTSAU and NAARM estimated average spice consumption at 7.58 kg per person annually, amounting to 2.31 lakh tonnes for the state, with seed spices valued at ₹200 crores (Kumar *et al.*, 2017). [15] However, most of this demand is met through imports due to limited local production.
Botanically, many seed spices belong to the Apiaceae family, known for their aromatic properties. Cumin, for example, is rich in volatile oil, fat, protein, and fiber (Sowbhagya, 2013) [37]. Coriander and fenugreek are similarly valued for culinary and health benefits. Coriander, traditionally cultivated during the Rabi season, is one of the more prevalent spice crops in

Telangana. However, cultivation area has dropped sharply, from around 2,013 hectares in 2023 to 515 hectares in 2024 (Statista, 2024) [39]. Despite this, it remains a vital part of intercropping systems, particularly with crops like mungbean and nigella, demonstrating high productivity under rainfed conditions (ICAR-IIFSR, 2023) [12]. Fenugreek, although primarily grown in Rajasthan and Gujarat, is increasingly adopted in Telangana due to its adaptability to dry conditions and nitrogen-fixing ability. Improved varieties such as Pusa Early Bunching have shown good performance locally (ICAR-NRCSS, 2022) [13].

Ajwain is well-suited to Telangana marginal soils and low-input farming, yielding 400-600 kg/ha under rainfed conditions (Sasikumar *et al.*, 2021) [33]. However, its expansion is constrained by agronomic challenges such as seed shattering during unseasonal rains (Spices Board India, 2022) [38]. Cumin is gaining ground in the state despite being mainly cultivated in western India. India produces over 70% of the global supply, and Telangana's rabi-season cultivation has potential. However, disease pressures like blight and wilt limit yields under humid conditions (Soni Choudhary and Jain, 2020) [36]. To improve production in Telangana, focus must be placed on the adoption of improved varieties, disease management, and farmer education. With targeted interventions, these crops can contribute meaningfully to the state's agricultural diversification and enhancing the farmer's income.

2. Materials and Methods

2.1 Seed Spice varieties

The present investigation was conducted during the Rabi seasons of 2023-2024 and 2024-2025 at the Horticultural Research Station, Adilabad, located at 19.6480° N latitude and 78.5321° E longitude, with an elevation of 257 meters above mean sea level (MSL). The major soil type is medium red lateritic, characterized by its naturally low moisture-holding capacity and slightly acidic nature with a pH of 6.31. Nutrient analysis indicated low nitrogen (200.6 kg/ha), moderate phosphorus (18.2 kg/ha), and high potassium (206.4 kg/ha) levels. The experimental material comprised a diverse set of seed spice genotypes, including improved varieties, locally adapted cultivars, and established standard checks. Details regarding the varietal characteristics of coriander, fenugreek, cumin, and ajwain included in the study are presented in Tables 1a-1d.

Table 1a: Varietal Characteristics of Coriander included in the study

Variety	Source / Developed By	Duration (days)	Average Yield (kg/ha)	Grain Type	Special Traits	Reference
ACr-1	NRCSS, Ajmer	100-110	1169	Medium bold, brown seeds	Stem gall resistant, Suitable for both herb and seed spice.	Lal *et al.*, 2023
ACr-2	NRCSS, Ajmer	120-130	1600-2000	Seeds are bold and oval in shape, brown in colour.	High essential oil content 0.52%; Stem gall resistant.	Lal *et al.*,2023
ACr-3	NRCSS, Ajmer	120-130	1,100-1,300	Medium bold, light brown	High essential oil content 0.55%, Moderately resistant to powdery mildew,	Meena *et al.*, 2023
AgCr-1	NRCSS, Ajmer	90-110	1253	Medium bold, light brown	Dual purpose, both green leaf and seed purpose. Powdery mildew resistance, suitable for off season cultivation.	Lal *et al.*, 2023
Suguna (LCC-236)	Dr. YSRHU, Andhra Pradesh	85-100	Rainfed 800-1400 Irrigated 1200-2200	Small to medium, oval shaped and light brown in colour	High essential oil content 0.52%; moderately resistant to powdery mildew	Reddy and Janakiran, 2023 [32]

Table 1b: Varietal Characteristics of Fenugreek included in the study

Variety	Developed by	Maturity (days)	Seed Yield (q/ha)	Seed Size / Weight	Special Traits	References
AFg-1	NRCSS, Ajmer	135 days	20-22 q/ha	Bold seeds; 17-20 g test weight; 17-20 seeds/pod	Dual-purpose for seed & leaves; bold large seeds	Shakthi *et al.*, 2020 [34]
AFg-2	NRCSS, Ajmer	140 days	15-18 q/ha	Small seeds; 16-18 seeds/pod	Medicinal value; dual-purpose	Shakthi *et al.*, 2020 [34]
AFg-3	NRCSS, Ajmer	140 days	15-18 q/ha	Bold seeds	Moderately resistant to powdery mildew and root rot	Shakthi *et al.*, 2020 [34]
AFg-4	NRCSS, Ajmer	120-130 days	19-19.25 q/ha	Small seeds; 14.6 seeds /pod	Moderately resistant to powdery mildew & root rot	Kakani *et al.*, 2023
AFg-5	NRCSS, Ajmer	140 days	17.2 q/ha	Bold, bigger seeds	Moderately resistant to powdery mildew and Alternaria blight	Shakthi *et al.*, 2020 [34]

Table 1c: Varietal Characteristics of Cumin included in the study

Variety	Source / Developed By	Duration (days)	Average Yield (kg/ha)	Grain Type	Special Traits	References
GC-1	SDAU, Jagudan, Gujarat	105-110 days	700 kg/ha	bold, linear, oblong ash brown colour seeds	Tolerant to wilt disease	Lal *et al.*, 2014 [17]
GC-2	SDAU, Jagudan, Gujarat	100 days	700 kg/ha	Attractive seeds	Good branching and bushy plants	Lal *et al.*, 2014 [17]
GC-3	SDAU, Jagudan, Gujarat	100 days	700 kg/ha	Medium-size, lustrous seeds	Essential oil 3.5%, Resistant to Fusarium wilt. Suitable for cooler winter seasons with limited irrigation	Lal *et al.*, 2014 [17]
GC-4	SDAU, Jagudan, Gujarat	105-110 days	875 kg/ha	bold, attractive seeds	Fusarium-wilt resistant	Lal *et al.*, 2014 [17]
Local (check)	Adilabad	130 days	500 kg/ha	Small seeds, dark brown seeds	Not studied	

Table 1d: Varietal Characteristics of Ajwain included in the study

Variety	Developed By	Duration (days)	Average Yield (kg/ha)	Grain Type	Special Traits	References
AA-1	NRCSS, Ajmer	165 days	1426 kg/ha	Bold seeded	suitable for cultivation both under irrigated and rain fed situations	Meena *et al.*,2009 [25]
AA-2	NRCSS, Ajmer	147 days	1283 kg/ha	-	Essential oil 3%, Early variety, Powdery mildew resistant.	Meena *et al.*,2009 [25]
AA-93	NRCSS, Ajmer	120-130 Days	1200 kg/ha	-	Short duration variety.	Meena *et al.*,2009 [25]
AA-73	NRCSS, Ajmer	165-170 days	1600 kg/ha	-	It shows high tolerance to *Root rot* and *Sclerotium rot*.	Meena *et al.*,2009 [25]
LS-1	Dr. YSRHU, Lam	135 days	800 kg/ha	-	-	Meena *et al.*,2009 [25]

2.2 Weather conditions

The experimental site is located in a semi-arid agro-climatic zone characterized by high summer temperatures and dry weather, with the majority of annual precipitation occurring during the South-West monsoon season. Summer temperatures can rise up to 46 °C, whereas winter temperatures may drop to around 15.9° C. Cold weather typically begins in late November. The average annual rainfall of the region is approximately 1157.6 mm, with nearly 85% of it received during the monsoon period.

Weather parameters including temperature, relative humidity, rainfall, and the number of rainy days were recorded throughout the cropping periods to facilitate interpretation of experimental results. These data are summarized in Table 2.

Table 2: Monthly weather data during the cropping periods of 2023-2024 and 2024-2025

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Rainfall (mm)	Rainy Days
2023-2024					
October 2023	14.5	32.3	76.2	0.0	0
November 2023	17.1	31.5	80.0	0.86	2
December 2023	15.5	32.4	80.3	0.0	0
January 2024	16.1	30.7	79.0	0.0	0
February 2024	19.3	33.7	63.0	0.5	0
March 2024	22.1	37.9	61.3	1.33	4
April 2024	25.1	40.1	69.9	0.91	3
2024-2025					
October 2024	23.1	34.0	84.9	35.6	3
November 2024	14.6	30.9	82.9	0.0	0
December 2024	14.0	29.9	79.5	5.6	1
January 2025	12.8	31.3	74.9	0.0	0
February 2025	15.3	34.1	55.7	0.0	0
March 2025	23.8	37.6	67.0	6.0	4
April 2025	28.0	41.0	69.9	13.78	3

(Source: Automatic Weather Station (AWS), Agricultural Research Station, Adilabad)

2.3 Experimental design

The experiment was laid out in a Randomized Block Design (RBD**)** with four replications. Treatments, comprising various seed spice varieties, were randomly allocated within each replication. Standard agronomic practices were followed uniformly across all plots. A summary of crop-specific management practices is presented in Table 3, and the crop calendar is provided in Table 4.

Observations were recorded on key growth parameters, flowering behavior, and seed yield components from five randomly selected plants per treatment in each replication. Mean values were computed and subjected to statistical analysis.

Table 3: Standard agronomic package of practices followed in raising the seed spices in the experimental plots

Practice	Ajwain	Coriander	Cumin	Fenugreek
Pre-emergence herbicide	Pendimethalin 30 EC @ 1.0 L/ha	Pendimethalin 30 EC @ 1.0 L/ha	Pendimethalin 30 EC @ 1.0 L/ha	Pendimethalin 30 EC @ 1.0 L/ha
Spacing (cm) and Seed rate (kg/ha)	30 × 20 cm; 3 kg/ha	15 × 15 cm; 12 kg/ha	25 × 10 cm; 12-16 kg/ha	30 × 10 cm; 12 kg/ha
Plant population (approx.)	166,667 plants/ha	444,444 plants/ha	400,000 plants/ha	333,333 plants/ha
Manures and fertilizers	40 kg N, 20 kg P_2O_5, 20 kg K_2O/ha applied at sowing	15 t FYM + 30:40:20 kg NPK/ha as basal dose; N applied in three splits	10 t FYM + 30:20:20 kg NPK/ha; half N + full P and K as basal, rest N at 30 and 60 DAS	20 t FYM + 30:25:40 kg NPK/ha as basal; 20 kg N as top dressing at 30 DAS
Weeding	Two manual weeding's and hoeing's; first at 30 DAS	Two manual weeding's and hoeing's	Two manual weeding's	Two manual weeding's at 10-20 and 40-50 DAS
Irrigation	Light irrigation at sowing, followed by flood irrigation every 15-25 days	Light irrigation at sowing; flood irrigation at 30-40 DAS (seedling), 50-60 DAS (grand growth), 70-80 DAS (flowering), and 90-100 DAS (seed formation)	Light irrigation at sowing; flood irrigation every 30 days; avoid irrigation at maturity	Light irrigation at sowing; irrigations on 30th, 75th, 85th, and 105th DAS
Plant protection	Neem oil 2% for sucking pests; Sulphur dusting @ 25 kg/ha for powdery mildew	Neem oil 2% for sucking pests; Mancozeb @ 3 g/L sprayed at flowering and seed formation for grain mould	Neem oil 2% for sucking pests	Neem oil 2% for sucking pests
Harvesting period	130-180 days after sowing	100-150 days after sowing	90-120 days after sowing	90-100 days after sowing

Table 4: Crop calendar followed in seed spice experimental plots during 2023-2024 and 2024-2025

A. Rabi Season 2023-2024

Operation	Ajwain	Coriander	Cumin	Fenugreek
Land Preparation	05 October 2023	06 November 2023	06 November 2023	06 November 2023
Seed Sowing	06 October 2023	08 November 2023	08 November 2023	08 November 2023
Thinning	08 November 2023	11 January 2024	10 January 2024	11 January 2024
Manual Weeding	06 November 2023 (1st), 08 December 2023 (2nd)	10 January 2024 (1st), 10 February 2024 (2nd)	08 January 2024 (1st), 08 February 2024 (2nd)	10 January 2024 (1st), 10 February 2024 (2nd)
Harvesting	26 February 2024	28 March 2024	11 March 2024	10 arch 2024

B. Rabi Season 2024-2025

Operation	Coriander	Cumin	Fenugreek
Land Preparation	14 October 2024	01 November 2024	14 October 2024
Seed Sowing	16 October 2024	03 November 2024	16 October 2024
Thinning	19 November 2024	06 January 2025	20 November 2024
Manual Weeding	17 November, 2024 (1st), 18 December 2024 (2nd)	04 January 2025 (1st), 05 February 2025 (2nd)	18 November 2024 (1st), 19 December 2024 (2nd)
Harvesting	03 March 2025	04 March 2025	16 February 2025

2.4 Statistical analyses
The data collected over both experimental years were pooled and subjected to analysis of variance (ANOVA) following the standard procedure for a Randomized Block Design (RCBD). Varietal means were compared using the Least Significant Difference (LSD) test at a 5% level of significance. Statistical analysis was performed using GRAPES software (Gopinath *et al.*, 2020) [11].

3. Results and Discussion
The results pertaining to various agronomic and yield-related parameters including plant height (cm), number of branches per plant, days to 50% flowering, number of umbels per plant, number of umbellates per umbel, number of seeds per umbel, 1000-seed weight (g), number of pods per plant, pod length (cm), and seed yield (kg/ha) were recorded and analyzed for different seed spice crops, namely ajwain, coriander, cumin, and fenugreek, and are presented and discussed below

3.1 Ajwain Varietal Performance (2023-24)
The performance of ajwain varieties for various growth and yield parameters during the Rabi season of 2023-24 is presented in Table 5. Among the varieties evaluated, AA-93 recorded the maximum plant height (105.85 cm), which was significantly higher than the local check. The variety AA-1 exhibited the highest number of branches per plant (18.47), followed by AA-93 (16.98) and AA-2 (15.50). The increased plant height and branching may be attributed to favorable soil moisture conditions at the time of sowing and the timely application of irrigation, which enhanced seedling germination and early vegetative growth (Sushma *et al.*, 2023).

The earliest flowering was observed in AA-93 (86.45 days to 50% flowering), followed by LS-1 (93.97 days). For yield-contributing traits, AA-1 showed significantly higher values for number of umbels per plant (212.20), umbellates per umbel (14.63), seeds per umbel (225.70), and 1000-seed weight (1.62 g). These were followed by AA-93, which also performed better than the local variety in all the mentioned traits. The superior reproductive traits observed in AA-1 and AA-93 may be linked to their early growth vigour and efficient translocation of stored carbohydrates, resulting in enhanced floral and seed development (Ranjeetha *et al.*, 2021) [30].

In terms of seed yield, AA-93 outperformed all other varieties with a yield of 1194.16 kg/ha, followed by AA-1 (1014.99 kg/ha). In contrast, the local variety recorded the lowest yield (641.66 kg/ha). The better yield performance of improved varieties is likely due to their superior genetic potential and positive interaction with the local agro-climatic conditions (Phurailatpam *et al.*, 2016; Telugu *et al.*, 2019; Asangi *et al.*, 2023) [29, 40, 4].

Table 5: Evaluation of ajwain varieties for growth, yield attributes, and seed yield (kg/ha) at Horticultural Research Station, Adilabad (2023-2024)

Variety	Plant Height (cm)	No. of Branches	Days to 50% Flowering	No. of Umbels/ Plant	Umbellates/ Umbel	Seeds/ Umbel	1000-Seed Weight (g)	Seed Yield (kg/ha)
AA-1	101.42	18.47	98.96	212.20	14.63	225.70	1.62	1014.99
AA-2	102.23	15.50	96.31	186.63	12.90	188.68	1.34	888.33
AA-93	105.85	16.98	86.45	203.31	13.20	222.84	1.40	1194.16
LS-1	95.64	14.13	93.97	109.33	11.24	154.66	1.21	829.99
Local	92.31	11.90	101.75	104.90	10.35	137.77	1.13	641.66
SE(m) ±	2.89	0.72	2.98	5.35	0.52	5.86	0.05	95.61
CD (p=0.05)	9.00	2.26	9.29	16.68	1.64	18.26	0.17	294.62
CV (%)	5.81	9.42	6.25	6.55	8.44	6.30	8.51	20.92

3.2 Coriander Varietal Performance (2023-24 and 2024-25)
The evaluation of coriander varieties over two Rabi seasons revealed significant differences in growth, phenological, and yield attributes, which were influenced by both genetic potential and prevailing agro-climatic conditions of the semi-arid zone of Adilabad (Table 6).

Plant Height and Branching

Among the five varieties evaluated, ACR-3 recorded the tallest plants with a pooled plant height of 88.76 cm, followed closely by ACR-1 (88.28 cm) and Suguna (85.52 cm). The lowest plant height was observed in AGCR-1 (73.38 cm). The differences in plant height may be attributed to genotypic variability and the interaction of varieties with soil and environmental conditions during the cropping seasons (Ravi *et al*., 2020) [31]. These findings are consistent with earlier reports by Verma *et al.*, (2014) [42]. In terms of primary branches per plant, ACR-1 (8.59) recorded the highest number, followed by ACR-3 (8.50) and Suguna (8.06), indicating better vegetative growth in these genotypes.

Days to 50% Flowering

Earliness in flowering is a desirable trait for short-season crops. The variety Suguna (LCC-236) flowered earliest (52.41 days), followed by ACR-3 (53.23 days) and ACR-1 (54.93 days). Delayed flowering was recorded in AGCR-1 (61.68 days), which may limit its suitability in regions with shorter growing windows. Early flowering contributes to timely maturity and better alignment with favorable climatic conditions.

Reproductive Attributes

ACR-1 consistently outperformed other varieties in several yield-determining traits. It recorded the highest number of umbels per plant (38.83), umbellates per umbel (6.02), seeds per umbel (30.04), and 1000-seed weight (9.30 g). These parameters play a crucial role in determining the final productivity of coriander. Suguna also showed promising results for seed number (28.49) and test weight (8.36 g), indicating its potential as a high-yielding genotype under irrigated conditions. The superior performance of these varieties may be attributed to their genetic makeup, which allowed efficient utilization of soil moisture and nutrients.

Seed Yield

In terms of seed productivity, ACR-1 recorded the highest pooled seed yield of 1827.08 kg/ha, followed by Suguna (1369.99 kg/ha) and ACR-2 (1357.49 kg/ha). Relatively lower yields were recorded for ACR-3 (812.49 kg/ha) and AGCR-1 (913.74 kg/ha). The enhanced seed yield in ACR-1 is likely due to a favorable combination of vegetative and reproductive traits. Yield variations among varieties may also be influenced by microclimatic factors, irrigation frequency, and soil moisture availability during the crop growth period. Similar trends of yield variation in coriander due to genotype-environment interactions have been reported by Garid *et al.*, (2015), Ravi *et al.*, (2020) [31], and Velayudham *et al.*, (2006) [41].

3.3 Cumin Varietal Performance (2023-24 and 2024-25)

The performance of five cumin varieties was assessed over two consecutive Rabi seasons under the semi-arid agro-climatic conditions of Adilabad. Significant differences were observed among the genotypes for various growth, phenological, and yield-contributing traits, highlighting the influence of genetic makeup and genotype x environment interactions (Table 7).

Plant Height and Branching

Among the tested genotypes, GC-4 recorded the tallest plants with a pooled mean height of 42.95 cm, followed by GC-3 (40.48 cm) and GC-1 (40.07 cm). The lowest plant height was noted in the local check (38.18 cm). The superior plant stature of GC-4 is indicative of its robust vegetative growth and adaptability to local soil and climatic conditions.

In terms of primary branches per plant, GC-4 again demonstrated superiority, with a pooled average of 5.35 branches, significantly outperforming GC-3 (5.03) and GC-1 (4.16). The increased branching in GC-4 could be attributed to its genetic potential and environmental responsiveness. Plant height and branching are crucial for early vigor, better canopy development, and enhanced photosynthetic activity, ultimately supporting greater reproductive success.

These results are supported by Akhter *et al*. (2023) [2], who reported a positive correlation between plant height, number of branches, number of umbels, and seed yield, emphasizing the role of these traits in enhancing cumin productivity.

Days to 50% Flowering

Phenological observations revealed that GC-4 flowered earliest (53.06 days), which is an important trait in semi-arid environments where early maturity helps avoid terminal drought stress. Later flowering was observed in GC-1 (57.75 days) and GC-2 (57.00 days). The significant differences among varieties (CD = 2.13) indicate substantial genotypic variation in flowering behavior. Earliness in GC-4 is advantageous for fitting within shorter Rabi seasons and maximizing resource use efficiency.

Reproductive and Yield Attributes

GC-4 consistently outperformed other varieties in all major reproductive traits. It recorded the highest number of umbels per plant (33.01), umbellates per umbel (6.03), seeds per umbel (23.55), and the boldest seeds with a 1000-seed weight of 3.09 g. These attributes directly contributed to its superior seed yield performance.

GC-3 and GC-1 also recorded comparatively higher values for reproductive traits than the local check, but remained inferior to GC-4. The local variety consistently recorded the lowest values for all yield attributes, including seed weight (2.17 g) and number of seeds per umbel (20.24).

These results corroborate earlier findings by Meena *et al.*, (2015) [23], Bairwa *et al.*, (2015) [5], and Mohit Kumar *et al*. (2021) [28], who emphasized the importance of yield-contributing traits such as umbels per plant, seed count, and seed weight in cumin varietal improvement programs.

Seed Yield

The pooled analysis clearly identified GC-4 as the highest yielding variety, recording 706.66 kg/ha, significantly outperforming GC-1 (614.58 kg/ha), GC-3 (546.24 kg/ha), and the local check (432.08 kg/ha). The superior yield performance of GC-4 can be attributed to its higher plant height, better branching, earlier flowering, greater number of umbels, and higher seed weight. This integrated advantage illustrates the role of both vegetative and reproductive traits in maximizing seed productivity.

3.4 Fenugreek Varietal Performance (2023-24 and 2024-25)

The performance of five fenugreek (*Trigonella foenum-graecum* L.) varieties was assessed over two consecutive Rabi seasons under the semi-arid agro-climatic conditions of Adilabad. Pooled data across the two years revealed significant genotypic differences for most growth and yield-related parameters, indicating the influence of both genetic potential and genotype × environment interactions (Table 8).

Plant Height and Branching

Significant variation in plant height was observed among the varieties. AFG-2 recorded the maximum plant height (71.38 cm), followed by AFG-4 (70.20 cm) and AFG-1 (69.22 cm), while the shortest plants were noted in AFG-5 (67.24 cm). These differences are likely attributed to inherent genetic variability, adaptability to local environmental conditions, and agronomic practices. Similar findings were reported by Latye *et al.*, (2016) [20], Aggarwal *et al.*, (2013) [1], and Duwal *et al.*, (2019) [8], who highlighted the role of plant height in biomass accumulation and yield potential. In terms of primary branching, AFG-2 again led with the highest number of branches per plant (6.15), followed by AFG-4 (5.69) and AFG-1 (5.43), whereas AFG-5 recorded the lowest number (4.58). Enhanced branching is closely associated with increased sink sites for pod formation and ultimately contributes to yield.

Days to 50% Flowering

Phenological observations revealed significant differences in flowering time among the varieties. AFG-3 flowered earliest at 42.26 days, followed by AFG-1 (43.60 days), whereas late flowering was observed in AFG-5 (46.10 days). Earliness is considered an agronomically beneficial trait under semi-arid conditions as it allows the crop to complete its lifecycle before the onset of terminal drought stress. These findings are consistent with reports by Chandra *et al.*, (2000) [6], Latye *et al.*, (2016) [20], and Aggarwal *et al.*, (2016) [1], who emphasized the importance of early flowering for adaptability and productivity in short-season environments.

Reproductive Attributes

Substantial variability was also observed in reproductive traits. AFG-1 recorded the highest number of pods per plant (38.20), followed closely by AFG-2 and AFG-4 (36.21 each), while AFG-3 produced the lowest pod count (32.29). Regarding pod length, AFG-1 exhibited the longest pods (12.26 cm), followed by AFG-2 (11.87 cm). Shorter pod lengths were recorded in AFG-3 (10.15 cm) and AFG-4 (10.38 cm). The number of seeds per pod was highest in AFG-1 (16.93), followed by AFG-2 (16.16), with AFG-4 recording the lowest seed count (14.06). AFG-1 also showed the highest 1000-seed weight (15.76 g), indicating the presence of bold and well-filled seeds, whereas AFG-4 had the lowest seed weight (13.47 g). These reproductive traits are critical determinants of yield, and the superior performance of AFG-1 in all these parameters reflects strong source-sink dynamics and efficient assimilate partitioning during seed development. Similar trends were reported by Chauhan *et al.*, (2017), [7] Jyothi and Hegde, (2018) [14], and Shakthi *et al.*, (2020) [34].

Seed Yield

Seed yield, the most economically important trait, varied significantly among the genotypes. AFG-1 achieved the highest pooled seed yield (1729.99 kg/ha), significantly outperforming the other entries. This was followed by AFG-2 (1445.83 kg/ha) and AFG-3 (1345.83 kg/ha). The lowest yields were recorded for AFG-5 (829.16 kg/ha) and AFG-4 (1091.66 kg/ha). The yield superiority of AFG-1 can be attributed to its favorable combination of traits, including higher pod number, longer pods, greater seeds per pod, and superior seed weight. These results are in accordance with earlier reports by Meena *et al.*, (2015) [23] and Kumar *et al.*, (2021) [28], who emphasized the importance of reproductive vigor and efficient assimilate translocation in enhancing seed yield in fenugreek.

Table 6: Evaluation of Coriander varieties for growth, yield attributes and seed yield (kg ha^{-1}) (2023-2024, 2024-2025 and Pooled)

Varieties	Plant height (cm)			Number of branches			Days to 50% flowering			No. of umbels/plant		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
Suguna (LCC-236)	90.48	91.50	85.52	8.10	8.02	8.06	52.75	52.07	52.41	31.30	34.05	30.62
ACR-1	88.78	75.50	88.28	8.73	8.45	8.59	55.38	57.50	54.93	40.63	37.05	38.83
ACR-2	79.55	71.50	82.98	7.58	7.44	7.51	59.68	60.75	58.58	34.05	29.95	34.05
ACR-3	93.06	88.75	88.76	8.75	8.26	8.50	53.25	53.22	53.23	27.95	25.93	26.94
AGCR-1	75.28	83.50	73.38	6.60	6.25	6.42	62.63	54.50	61.68	25.25	25.77	25.51
SE(m)±	3.67	0.69	1.70	0.39	0.18	0.18	1.82	0.58	0.43	1.34	0.88	0.46
CD (p=0.05)	11.64	2.13	NS	1.22	0.55	0.56	5.68	1.8	1.34	4.20	2.70	1.43
CV (%)	8.61	1.68	17.41	9.86	4.65	2.56	6.42	2.10	3.05	8.47	5.74	7.99

Varieties	No. of umbellate per umbel			No. of seeds per umbel			1000 seed weight (g)			Seed yield (kg/ha.)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
Suguna (LCC-236)	4.60	5.52	5.06	28.66	28.32	28.49	8.58	6.15	8.36	1289.99	1449.99	1369.99
ACR-1	6.08	5.97	6.02	30.91	29.17	30.04	9.66	8.95	9.30	1845.83	1808.33	1827.08
ACR-2	5.15	4.70	4.92	29.66	27.20	28.43	6.65	8.15	6.40	1489.99	1224.99	1357.49
ACR-3	4.43	4.30	4.36	27.81	26.27	27.04	5.70	5.35	5.52	944.16	783.33	812.49
AGCR-1	4.03	4.01	4.02	27.29	26.42	26.85	5.34	5.30	5.31	841.66	883.33	913.74
SE(m)±	0.23	0.09	1.09	0.78	0.09	1.97	0.30	0.08	0.15	38.75	37.11	94.56
CD (p=0.05)	0.72	0.27	3.41	2.44	0.28	6.16	0.95	0.23	0.48	119.43	114.35	295.53
CV (%)	9.60	3.63	13.13	5.43	0.65	4.04	8.54	2.25	4.96	6.05	6.03	16.95

Table 7: Evaluation of cumin varieties for growth, yield attributes, and seed yield (kg ha^{-1}) (2023-2024, 2024-2025 and Pooled)

Varieties	Plant height (cm)			Number of branches			Days to 50% flowering			No. of umbels/plant		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
GC-1	40.42	39.72	40.07	4.52	3.75	4.16	57.25	58.25	57.75	32.67	29.77	31.25
GC-2	39.94	39.35	39.39	3.34	2.95	3.14	58.50	55.50	57.00	28.92	26.27	27.47
GC-3	41.29	40.17	40.48	5.47	4.60	5.03	59.47	58.75	59.11	32.03	24.25	28.14
GC-4	43.50	42.40	42.95	5.86	4.85	5.35	53.37	52.75	53.06	34.49	31.52	33.01
Local	38.86	37.50	38.18	3.85	3.45	3.65	56.47	54.50	55.48	30.92	28.87	29.90
SE(m)±	0.96	0.48	0.30	0.21	0.14	0.34	0.47	1.19	0.68	1.14	0.63	0.94
CD (p=0.05)	2.99	1.48	0.95	0.65	0.42	1.06	1.45	3.69	2.13	3.55	1.93	NS
CV (%)	4.71	2.40	1.71	9.12	7.00	7.07	1.65	4.28	3.67	7.17	4.46	11.14

Varieties	No. of umbellate per umbel			No. of seeds per umbel			1000 seed weight (g)			Seed yield (kg/ha.)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
GC-1	5.30	5.00	5.15	23.77	21.32	22.25	2.84	2.25	2.54	619.99	609.16	614.58
GC-2	4.74	4.15	4.44	21.85	20.65	21.28	2.49	2.30	2.39	503.33	514.99	509.16
GC-3	5.50	4.77	5.13	22.71	21.62	22.30	2.65	2.45	2.55	559.16	533.33	546.24
GC-4	6.39	5.67	6.03	24.35	22.70	23.55	3.14	3.05	3.09	721.66	691.66	706.66
Local	4.67	4.22	4.48	20.85	19.55	20.24	2.40	1.95	2.17	475.83	388.33	432.08
SE(m)±	0.15	0.13	0.12	0.78	0.34	0.16	0.12	0.08	0.13	41.27	23.78	23.44
CD (p=0.05)	0.48	0.42	0.36	2.41	1.04	0.498	0.38	0.26	0.41	127.19	73.28	72.24
CV (%)	5.83	5.67	5.13	6.90	3.19	1.63	9.14	6.97	11.45	14.33	8.69	9.26

Table 8: Evaluation of fenugreek varieties for growth, yield attributes, and seed yield (kg ha^{-1}) (2023-2024, 2024-2025 and Pooled)

Varieties	Plant height (cm)			Number of branches			Days to 50% flowering			No. of Pods/plant		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
AFG-1	69.37	68.81	69.22	5.65	5.22	5.43	42.45	42.95	43.60	38.62	37.78	38.20
AFG-2	71.52	71.24	71.38	6.40	5.91	6.15	45.80	43.40	45.25	36.52	35.89	36.21
AFG-3	68.95	68.51	68.60	5.17	5.11	5.14	40.50	44.17	42.26	32.65	31.93	32.29
AFG-4	70.52	70.13	70.20	5.75	5.63	5.69	43.17	45.55	44.88	33.27	32.58	36.21
AFG-5	67.32	67.16	67.24	4.52	4.57	4.58	46.37	47.62	46.10	36.00	32.89	34.44
SE(m)±	0.83	0.21	0.18	0.23	0.15	0.15	1.33	0.18	1.97	1.26	0.61	0.30
CD (p=0.05)	2.58	0.64	0.55	0.72	0.47	0.47	4.16	0.56	NS	3.92	1.89	0.95
CV (%)	2.38	0.60	0.57	8.40	5.78	6.22	6.13	0.81	4.196	7.11	3.58	3.23

Varieties	Pod length (cm)			No. of seeds per pod			1000 seed weight (g)			Seed yield (kg/ha.)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
AFG-1	12.65	12.37	12.26	17.85	16.67	16.93	16.42	15.10	15.76	1491.66	1716.66	1729.99
AFG-2	12.00	12.24	11.87	16.95	15.72	16.16	15.60	14.22	14.91	1116.66	1424.99	1445.83
AFG-3	10.50	10.30	10.15	15.50	14.77	15.00	14.52	13.65	14.08	799.99	1391.66	1345.83
AFG-4	10.77	10.50	10.38	14.47	13.85	14.06	13.65	13.30	13.47	406.66	1216.66	1091.66
AFG-5	11.52	11.20	11.11	16.65	13.47	14.63	15.27	14.50	14.88	508.33	891.66	829.16
SE(m)±	0.47	0.13	0.15	0.64	0.20	0.51	0.56	0.20	0.27	56.41	41.30	76.43
CD (p=0.05)	1.49	0.40	0.46	2.00	0.63	1.58	1.75	0.63	0.83	173.83	127.27	238.85
CV (%)	8.32	2.29	2.98	7.88	2.73	7.42	7.44	2.89	4.09	12.87	6.22	13.13

4. Conclusion

The multi-season evaluation of four seed spices coriander, cumin, fenugreek, and ajwain under the semi-arid conditions of Adilabad revealed significant varietal differences in growth, phenological development, and yield attributes. The results underscore the critical role of genotype × environment interactions and highlight the potential of improved varieties to enhance spice productivity and profitability in resource-constrained agro-ecologies.

In coriander, ACR-1 demonstrated superior performance across all yield-contributing traits including number of umbels per plant, seeds per umbel, 1000-seed weight, and branching, resulting in the highest pooled seed yield (1827.08 kg/ha). Suguna (LCC-236) and ACR-2 also performed well, making them suitable alternatives for irrigated or moderately dry conditions. Early flowering in Suguna suggests its appropriateness for shorter Rabi seasons.

Among cumin genotypes, GC-4 outperformed other entries with maximum plant height, early flowering, greater number of umbels per plant, bold seed weight, and highest pooled seed yield (706.66 kg/ha). This variety showed excellent adaptability to local climatic conditions and is recommended for commercial adoption. GC-1 and GC-3 exhibited moderate productivity and stable performance across seasons, while the local check recorded the lowest yield, indicating the benefits of varietal substitution.

In fenugreek, AFG-1 emerged as the most productive variety with the highest seed yield (1729.99 kg/ha), supported by a favorable combination of vegetative vigor, early flowering, and robust reproductive traits such as pod length, seed number, and 1000-seed weight. AFG-2 and AFG-3 were also promising, particularly in terms of branching and earliness, respectively. These varieties offer flexible options depending on seasonal length and resource availability.

In ajwain, although overall yield levels were relatively lower compared to other seed spices, significant varietal differences were observed. AA-93 consistently recorded the highest seed yield and superior values for reproductive traits including umbels per plant and test weight. Its early flowering and adaptability to terminal moisture stress conditions make it a promising choice for cultivation under limited irrigation. Other varieties such as AA-1 and AA-2 also showed stable performance and could serve as reliable options for diversified spice farming systems.

Overall, the study establishes that targeted varietal selection based on local agro-climatic suitability and performance stability is key to enhancing seed spice productivity. The varieties ACR-1 (coriander), GC-4 (cumin), AFG-1 (fenugreek), and AA-93 (ajwain) emerged as the most promising genotypes for the semi-arid tracts of Telangana. Their adoption can contribute significantly to sustainable intensification, income diversification, and resilience in spice-based cropping systems.

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