



Reviewed by

Dr. R.S. Meena
ICAR-National Research Centre on
Seed Spices,
Tabiji, Ajmer – 305206, Rajasthan, India
Email: rsm.nrcss@gmail.com

*Correspondence

P. J. Patel
rsspices@sdau.edu.in

Received: 24 April 2026

Revision: 20 May 2026

Accepted: 13 August 2026

Citation

Patel, R.N., Patel, P.J., and Patel, D.G., 2025. Extent of natural cross-pollination and standardization of isolation distance in cumin (*Cuminum cyminum* L.). Int J Seed Spice. 15 (2): 68-72

DOI

<https://doi.org/10.56093/IJSS.v15i2.9>

Affiliation

¹Department of Seed Technology, S. D. Agricultural University,
Sardarkrushinagar

²Seed Spices Research Station, S. D. Agricultural University, Jagudan

³Agriculture Research Station, S. D. Agricultural University, Ladol

Extent of natural cross-pollination and standardization of isolation distance in cumin (*Cuminum cyminum* L.)

R.N. Patel¹, P.J. Patel^{2*} and D.G. Patel³

Abstract

The present investigation was undertaken to assess the extent of natural outcrossing and to standardize the isolation distance required for genetic purity maintenance for cumin (*Cuminum cyminum* L.) seed production. The study was conducted at the Department of Seed Technology, S. D. Agricultural University, Sardarkrushinagar, and the Seed Spices Research Station (SSRS), S.D. Agricultural University, Jagudan. Cumin pollen contaminators carrying distinct phenotypic markers, viz., white flowers and hairy seeds, were used to assess pollen-mediated outcrossing. The contaminator genotypes were planted during Rabi 2011–12 and 2012-13, and progeny samples were evaluated for outcrossing at five distances (10, 20, 30, 40 and 50 m) in four directions (east, west, north and south). Grow-out test of the progenies conducted during Rabi 2013–14 revealed no detectable outcrossing (0%) at any of the distances or directions for either contaminator type. The absence of detectable cross-pollination even at the closest tested distance of 10 m indicates that pollen-mediated gene flow in cumin is negligible under the conditions of the present study, confirming its predominantly self-pollinated nature. Based on these findings, an isolation distance of 10 m may be sufficient for certified, foundation and breeder seed production of cumin. The results provide useful evidence for reviewing and refining the existing isolation-distance requirements for maintaining genetic purity in cumin seed production.

Keywords: Cumin, isolation distance, outcrossing, pollen contaminators, pollination

Introduction

Cumin (*Cuminum cyminum* L.) is an important annual seed spice belonging to the family *Apiaceae*, with a chromosome number of $2n = 2x = 14$. It is cultivated extensively in several countries, including India, Pakistan, Iran, Turkey, Syria, Morocco and Greece. India is the world's leading producer and exporter of cumin, with Gujarat and Rajasthan serving as the major production hubs. In Gujarat, cumin

occupied 476,557 ha during 2024-25, producing 471,838 metric tonnes with an average productivity of 0.99 metric tonnes ha⁻¹ (Directorate of Horticulture, Department of Agriculture, Farmers Welfare and Co-operation, Government of Gujarat). In addition to its economic significance, cumin has long been valued as an aromatic and functional spice owing to its medicinal, nutraceutical and pharmaceutical properties. Its seeds and essential oil are widely used in food and beverage products and in pharmaceutical, perfumery and toiletry industries (Allaq *et al.*, 2021).

The reproductive biology of cumin is of particular importance in relation to varietal maintenance and seed production. Cumin produces small, delicate, pink and white coloured flowers, which make controlled artificial pollination relatively difficult. The seeds are small, oblong, hairy and non-hairy types, dorsally compressed schizocarps, generally measuring 3-5 mm in length. The floral structure and small flower size may favour pollen transfer by insect pollinators, including honey bees, thereby creating a possibility of natural cross-pollination between closely growing varieties. As a result, most of the existing cumin varieties have been developed through selection-based conventional breeding rather than extensive hybridization programmes (Concepts and Strategies in Plant Sciences, 2024).

Maintenance of genetic and varietal purity is a critical requirement in quality seed production, particularly in crops where pollen-mediated gene flow can occur. Currently, two to three cumin varieties are under the seed chain; however, the number of varieties is expected to increase in the future, necessitating adequate facilities for the effective maintenance of breeding programmes (Kumar *et al.*, 2025). Natural outcrossing between neighbouring varieties may introduce foreign pollen and lead to genetic contamination, ultimately affecting the purity and quality of the seed lot. The magnitude of such contamination depends on several factors, including floral biology, pollinator activity, pollen dispersal and the distance between source and recipient plants. Therefore, scientifically established isolation distances are essential for minimizing unwanted cross-pollination during seed production. The Indian Minimum Seed Certification Standards (2013) currently recommend

an isolation distance of 400 m for certified seed and 800 m for foundation and breeder seed production in cumin. However, these recommended isolation distances have not been adequately supported by systematic experimental estimates of natural outcrossing in cumin under field conditions. Information on the actual extent of pollen-mediated outcrossing and accordingly fixation of isolation distance remains limited. Generating such information is essential for assessing whether the existing isolation standards are appropriate or require refinement.

Therefore, the present study was undertaken to quantify the extent of natural outcrossing in cumin under field conditions and to evaluate pollen-mediated varietal contamination at different spatial distances. The findings are expected to provide a scientific basis for optimizing isolation requirements and strengthening the production of genetically pure cumin seed.

Methodology

The experiment was conducted at the Department of Seed Technology, S. D. Agricultural University, Sardarkrushinagar, and the Seed Spices Research Station (SSRS), S.D. Agricultural University, Jagudan for three consecutive Rabi seasons (2011-12, 2012-13 and 2013-14). The study comprised 20 treatments involving four directions (east, west, north and south) and five isolation distances (10, 20, 30, 40 and 50 m), with three replications. The crop was sown at a spacing of 30 cm between rows and 5-10 cm between plants. All recommended agronomic and crop management practices were followed throughout the experimental period to ensure proper crop growth and development.

Experimental Design

The experiment was conducted to assess natural cross-pollination and pollen-mediated gene flow in cumin under field conditions. Cumin variety Gujarat Cumin-4 (GC-4), characterized by pink flowers and non-hairy seeds, was used as the female parent. Cumin types possessing white flowers and hairy seeds, which express dominant marker traits, were used as pollen donors (male parents) for assessing natural cross-pollination. The seed material was obtained from the Seed Spices Research Station (SSRS), S. D. Agricultural University, Jagudan. Hairy seed cumin and white flower cumin (Pollen donor) were sown separately in the centre of the experimental field, each

occupying a plot of 5 m × 5 m. To ensure synchronous flowering and facilitate natural cross-pollination, seeds of the cumin variety GC 4 were also broadcast within each central pollen donor plot. The female parent, GC 4, was sown in plots measuring 2.0 m × 1.5 m in the four cardinal directions, namely north, south, east, and west, at isolation distances of 10, 20, 30, 40, and 50 m from the central pollen donor plots. This experimental layout was adopted to estimate the percentage of natural outcrossing at different isolation distances and directions under field conditions.

At maturity, seeds harvested from the female-parent plots were evaluated for the presence of the dominant hairy-seed/white-flower trait as an indicator of pollen-mediated outcrossing. The proportion of hairy seeds hairy-seed/white-flower among the progeny was used to estimate the percentage of natural cross-pollination at each isolation distance and direction.

Natural Cross-Pollination Experiment

Fifty plants were randomly selected from each treatment for sampling. In the hairy-seed cumin plots, 50 plants each of the hairy-seed cumin and GC-4 were randomly selected, tagged, and harvested individually at maturity. Similarly, in the white-flowered cumin plots, 50 plants each of the white-flowered cumin and GC-4 were randomly selected, tagged, and harvested separately. Individual plant harvesting was carried out to facilitate subsequent progeny evaluation and estimation of natural outcrossing. Similarly, at varying isolation distance from each direction also, random samples of GC-4 variety were collected at maturity stage to evaluate the outcrossing in next progenies.

Plant-to-Progeny Evaluation

Individually harvested plants from both experimental combinations (hairy-seeded cumin × GC-4 and white-flowered cumin × GC-4) were sown separately in a plant-to-progeny-row arrangement. The progenies were evaluated for natural outcrossing based on the expression of the dominant marker traits, following the expected Mendelian inheritance pattern for monohybrid cross. The percentage of outcrossing was estimated from the proportion of progeny plants expressing the dominant marker phenotype (Results are presented in table 1).

Similarly, random samples from all 20 treatment combinations (4 directions × 5 isolation distances) were

sown in a Randomized Block Design (RBD) with three replications in plots measuring 2.0 m × 1.5 m at two locations: the Department of Seed Technology, S. D. Agricultural University, Sardarkrushinagar, and the Seed Spices Research Station (SSRS), S. D. Agricultural University, Jagudan. The experiment was conducted to assess the influence of isolation distance on natural outcrossing, based on the expression of dominant morphological marker traits in the progeny under a plant-to-plot evaluation system (Table 2).

Results and Discussion

The results of the Grow-Out Test (GOT) conducted at the Department of Seed Technology, S. D. Agricultural University, Sardarkrushinagar, are presented in Table 1. Progeny evaluation revealed that all plants derived from hairy-seeded cumin produced only hairy-seeded progeny, indicating 0% natural outcrossing. Similarly, the GC-4 plants grown within the hairy-seeded cumin pollen-donor plot consistently produced progeny exhibiting the characteristic GC-4 phenotype, with no evidence of pollen-mediated outcrossing. A similar trend was observed in the white-flowered cumin population. Progeny testing of the white-flowered cumin plants showed complete expression of the respective marker phenotype, while GC-4 plants grown within the white-flowered cumin plot retained the characteristic GC-4 phenotype. The presence of two distinct and dominant morphological marker traits (hairy seed over non-hairy seed and white flower colour over pink flower colour) provided an effective means of detecting pollen-mediated gene flow. Similarly, the results of grow out test for all 20 combinations (Table 2) revealed that no cross-pollination (hairy and white type flower) was observed in cumin at any isolation distance in all four directions. Any successful cross-pollination between the marker-bearing pollen donor and GC-4 would be expected to result in segregation of the marker traits in the subsequent progeny, following the principles of Mendelian inheritance (Griffiths, 2005 & Abbott & Fairbanks, 2016). Therefore, the complete absence of marker-derived progeny in the tested GC-4 plants provides strong evidence of negligible or no detectable natural outcrossing under the experimental conditions. These findings indicate that cumin exhibits a predominantly self-pollinating reproductive behaviour, with natural cross-pollination being

extremely low or negligible. The mechanisms responsible for this high degree of self-pollination in cumin, including homogamy, cleistogamy, floral

morphology, and the spatial and temporal arrangement of male and female reproductive organs need further investigation.

Table 1: Per cent cross-pollination in individual plant progenies of 50 plants in each treatment at Department of Seed Technology, S. D. Agricultural University, Sardarkrushinagar

Treatments	Plants in progeny	% Cross pollination
Hairy seed cumin	Hairy seed	0
GC 4 in Hairy seed cumin plot	GC 4 type	0
White flower cumin	White flower	0
GC 4 in White flower cumin	GC 4 type	0

Table 2: Per cent contamination in Grow-Out Test (GOT) conducted in Rabi 2012–13 and Rabi 2013–14

Direction / Distance	Department of Seed Technology, Sardarkrushinagar		Seed Spices Research Station (SSRS), Jagudan	
	White flower plants (%)	Hairy seed plants (%)	White flower plants (%)	Hairy seed plants (%)
North				
10 m	0	0	0	0
20 m	0	0	0	0
30 m	0	0	0	0
40 m	0	0	0	0
50 m	0	0	0	0
South				
10 m	0	0	0	0
20 m	0	0	0	0
30 m	0	0	0	0
40 m	0	0	0	0
50 m	0	0	0	0
East				
10 m	0	0	0	0
20 m	0	0	0	0
30 m	0	0	0	0
40 m	0	0	0	0
50 m	0	0	0	0
West				
10 m	0	0	0	0
20 m	0	0	0	0
30 m	0	0	0	0
40 m	0	0	0	0
50 m	0	0	0	0

Conclusion

The present investigation demonstrated that cumin is a predominantly self-pollinated crop, with negligible natural outcrossing under field conditions. Based on the observed pollen-mediated gene flow at different distances and directions, an isolation distance of 10 m is considered adequate to maintain the genetic purity of cumin seed. Accordingly, a minimum isolation distance of 10 m from other cumin varieties or related species is recommended for the production of breeder, foundation, and certified seed instead of 800 m and 400 m for foundation and certified seed production as mentioned in IMSCS. This recommendation provides a practical basis for maintaining varietal purity and ensuring quality seed production in cumin.

Conflict of Interest

The authors declare that there is no conflict of interest associated with this publication.

References

- Abbott, S. and Fairbanks, D.J. 2016. Experiments on plant hybrids by Gregor Mendel. *Genetics*, 204(2): 407–422.
- Allaq, A.A., Sidik, N.J., Abdul-Aziz, A. and Ahmed, I.A. Cumin (*Cuminum cyminum* L.): A review of its ethnopharmacology, phytochemistry. *Biomed Res Ther*, 7(9): 4016–4021.
- Chittaranjan Kole. 2024. *Genetics, genomics and breeding of seed spices*. ISBN 978-981-97-9630-4.
- Directorate of Horticulture. 2024–25. Department of Agriculture, Farmers' Welfare and Cooperation, Government of Gujarat.
- Griffiths, A.J. 2005. *An introduction to genetic analysis*. Macmillan.
- Indian Minimum Seed Certification Standards. 2013. Central Seed Certification Board, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi.
- Kumar, S., Ravi, Y., Meena, S.S., Meena, R.S., Meena, M.D., Sharma, Y.K., Meena, S.S., Tripathi, K.P. and Bhardwaj, V. 2025. Quantitative insights into breeder seed production trends and varietal adoption in major seed spices. *Int J Seed Spices*, 14(2): 1–11. doi: 10.56093/IJSS.v14i2.9.
- Research accomplishments and recommendations. 2014. Publication No. 01/2014. Directorate of Research, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat.