

EVALUATION OF GERMPLASM OF CUMIN (*Cuminum cyminum* Linn.) UNDER SUBTROPICS OF JAMMU

**By
Amreena Akhter
(J-17-M-494)**

**Thesis submitted to Faculty of Postgraduate Studies
in partial fulfillment of the requirements
for the degree of**

**MASTER OF SCIENCE
IN
FORESTRY**



**Division of Agroforestry
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu,
Main Campus, Chatha, Jammu- 180009
2019**

CERTIFICATE-I

This is to certify that the thesis entitled "Evaluation of Germplasm of Cumin (*cuminum cyminum* Linn.) Under Subtropics of Jammu" Submitted in partial fulfillment of the requirements for the degree of **Master of Science in Forestry** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu is a record of bonafide research, carried out by **Ms. Amreena Akhter** (Registration No. J-17-M-494) under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that such help and assistance received during the course of investigation have been duly acknowledged.


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CERTIFICATE II

We, the members of Advisory Committee of **Ms. Amreena Akhter**, Registration Number **J-17-M-494**, a candidate for the degree of **Master of Science in Forestry** have gone through the manuscript of the thesis entitled **“Evaluation of Germplasm of Cumin (*Cuminum cyminum* Linn.) under Sub-tropics of Jammu”** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the award of degree.



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Place: Chatha, Jammu

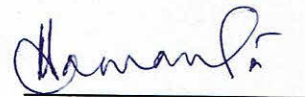
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This is to certify that the thesis entitled “**Evaluation of Germplasm of Cumin** (*Cuminum cyminum* Linn.) under Subtropics of Jammu” submitted by **Ms. Amreena Akhter**, Registration Number **J-17-M-494**, to the Faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu in partial fulfillment of the requirement for the degree of **Master of Science in Forestry** was examined and approved by the Advisory Committee and External Examiner on 18-11-2019.



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ACKNOWLEDGEMENT

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Place : Jammu

Date: 20-11-2019


Amreena Akhter

ABSTRACT

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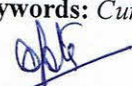
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ABSTRACT

Cuminum cyminum Linn. belonging to family Apiaceae, is commonly used spice in every household in India. Seeds yield a volatile oil (2.5-4.5%), the chief constituent of which is cuminaldehyde (20-40%), is used in perfumery and also for flavouring liquors and cordials. Seeds are very good source of iron and manganese and are also used as a condiment and form an essential ingredient in all mixed spices and curry powder for flavouring soups, pickles and for seasoning breads and cakes. The present investigation was carried out to find out the crop performance and to evaluate different genotypes of cumin for their growth and yield parameters under Jammu subtropics so as to get information on variability present in them and to identify superior genotype(s) for subtropics of Jammu region. Although moderate seed germination percentage (48.60-74.37%) was recorded, but the survival percentage of the crop was very poor (5.67% -12.33%) resulting in low seed yield plant⁻¹ (0.21g -0.98g) which ultimately lead to low yield per hectare (7.42kg-77.42kg), highest being in genotype GC-4. Wide range of variability was observed for all characters except for plant height and 1000 seed weight. Higher values for GCV and PCV were observed for number of seeds per plant (46.58%, 50.08%, respectively), seed yield per plant (49.60%, 52.25%) and seed yield plot⁻¹ (75.69%, 77.47%). Higher values for heritability accompanied with higher genetic gain was observed for number of seeds umbel⁻¹ (78.98%, 54.10%), number of seeds plant⁻¹ (86.54%, 89.25%), seed yield per plant (90.14%, 97.02%) and seed yield plot⁻¹ (95.46% and 152.35%). All the characters and combinations were positively and significantly correlated with each other except for trait pairs number of umbels plant⁻¹ vs. plant height, 1000 seed weight vs. plant height and 1000 seed weight vs. number of umbels plant⁻¹ which were positively correlated but non-significant. Seed yield plant⁻¹ was significantly and positively correlated with number of seeds plant⁻¹ ($r = 0.923$, $p = 0.01$), number of seeds umbel⁻¹ ($r = 0.842$, $p = 0.01$) survival percentage ($r = 0.825$, $p = 0.01$), number of umbels plant⁻¹ ($r = 0.787$, $p = 0.01$), germination percentage ($r = 0.750$, $p = 0.01$) and number of branches plant⁻¹ ($r = 0.710$, $p = 0.01$). Higher seed yield plant⁻¹ was observed in genotype GC-4 (0.98g) compared to other genotypes. The overall performance of different genotypes was poor, however, the genotype GC-4 performed better than others. Due to poor survival, growth and yield performance cumin crop is not commercially suitable for Jammu subtropics.

Keywords: *Cuminum cyminum*, variability, varieties, correlation, seed yield


(Major Advisor)


(Student)

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ABBREVIATIONS AND SYMBOLS USED

%	Per cent
m	Meter
mt	Million tones
cm	Centimeter
ha	Hectare
kg	Kilogram
°C	Degree Celsius
<i>et al.</i>	And others
g	Gram
GCV	Genotypic coefficient of variation
PCV	Phenotypic coefficient of variation
amsl	Above mean sea level
SE(m)	Standard Error of the mean
RBD	Randomized Block Design
C.D_{0.05}	Critical difference at 5% level of significance
IW	Irrigation Water Depth
SKNAU	Sri Karan Narendra Agriculture University
Fig.	Figure

Acknowledgements

ACKNOWLEDGEMENT

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Cuminum cyminum Linn. belonging to family Apiaceae, is commonly used spice in every household in India. Seeds yield a volatile oil (2.5-4.5%), the chief constituent of which is cuminaldehyde (20-40%), is used in perfumery and also for flavouring liquors and cordials. Seeds are very good source of iron and manganese and are also used as a condiment and form an essential ingredient in all mixed spices and curry powder for flavouring soups, pickles and for seasoning breads and cakes. The present investigation was carried out to find out the crop performance and to evaluate different genotypes of cumin for their growth and yield parameters under Jammu subtropics so as to get information on variability present in them and to identify superior genotype(s) for subtropics of Jammu region. Although moderate seed germination percentage (48.60-74.37%) was recorded, but the survival percentage of the crop was very poor (5.67% -12.33%) resulting in low seed yield plant⁻¹ (0.21g -0.98g) which ultimately lead to low yield per hectare (7.42kg-77.42kg), highest being in genotype GC-4. Wide range of variability was observed for all characters except for plant height and 1000 seed weight. Higher values for GCV and PCV were observed for number of seeds per plant (46.58%, 50.08%, respectively), seed yield per plant (49.60%, 52.25%) and seed yield plot⁻¹ (75.69%, 77.47%). Higher values for heritability accompanied with higher genetic gain was observed for number of seeds umbel⁻¹ (78.98%, 54.10%), number of seeds plant⁻¹ (86.54%, 89.25%), seed yield per plant (90.14%, 97.02%) and seed yield plot⁻¹ (95.46% and 152.35%). All the characters and combinations were positively and significantly correlated with each other except for trait pairs number of umbels plant⁻¹ vs. plant height, 1000 seed weight vs. plant height and 1000 seed weight vs. number of umbels plant⁻¹ which were positively correlated but non-significant. Seed yield plant⁻¹ was significantly and positively correlated with number of seeds plant⁻¹ ($r = 0.923$, $p = 0.01$), number of seeds umbel⁻¹ ($r = 0.842$, $p = 0.01$) survival percentage ($r = 0.825$, $p = 0.01$), number of umbels plant⁻¹ ($r = 0.787$, $p = 0.01$), germination percentage ($r = 0.750$, $p = 0.01$) and number of branches plant⁻¹ ($r = 0.710$, $p = 0.01$). Higher seed yield plant⁻¹ was observed in genotype GC-4 (0.98g) compared to other genotypes. The overall performance of different genotypes was poor, however, the genotype GC-4 performed better than others. Due to poor survival, growth and yield performance cumin crop is not commercially suitable for Jammu subtropics.

Keywords: *Cuminum cyminum*, variability, varieties, correlation, seed yield

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Introduction

INTRODUCTION

Agricultural production in the tropics and sub-tropics may get threatened due to global warming especially under rainfed/dryland conditions. To mitigate the consequences of climate change, it is imperative to diversify agriculture in rainfed areas to sustain the livelihood. Crop diversification and growing of large number of crops are practiced in dry-land areas to reduce the risk factor of crop failures due to recurring droughts. Crop substitution and crop shift are also taking place in the areas suffering with some specific soil related problems. Incorporation of medicinal, aromatic, spices, horticulture, floriculture, plantation crops etc. in agricultural lands is a viable option for diversification. The vast area and the agro-climatic conditions of India ranging from tropical to temperate make it possible to grow almost all the different kinds of plantation crops, medicinal, aromatic plants and spices.

Spices are the most fascinating vegetation, holding a significant position in human life. This mouth watering ingredient is an essential component of human food. The association of spices and mankind is prehistoric and multifarious. India was rightfully proclaimed as the “Land of spices”, indicating the largest natural collection of this treasure. Spices are indispensable part of our culinary preparations, they have potential medicinal values and are also used in flavouring agents. Apart from flavouring and seasoning, spices are widely used in pharmaceuticals, nutraceuticals, aroma therapy, preservatives, beverages, perfumes, dental preparations, cosmetics and botanicals as pesticide and thus play a significant role in developing the economy of the country (Tiwari and Agarwal, 2004).

India is the largest producer, consumer and exporter of spices. India's spice production and export is being increasing over the years and this increase is due to higher domestic consumption as well as export. This trend is expected to continue, as more and more spices are put to diversified use. India produces spices on 3.08 million ha area with an annual production of about 5.4 million tonnes valued at about Rs 4500 crores contributing nearly 20 per cent of world's production. India is biggest exporter of spices exporting about 445000 tonnes of spices and spice products valued around Rs. 4460 crores (Kumar, 2018).

Among the spices, the seed spices have emerged as one of the important group of spice crops in India. The seed spices account for about 36 per cent and 17 per cent of the total area and production of spices in the country. The spices are grown in about 1.74 million hectares, with production of 1.45 million tonnes annually (NRCSS, 2018). Coriander, cumin, fennel and fenugreek are the major seed spices besides celery, ajowan, dill, nigella, anise and caraway are being cultivated in smaller area. The states where seed spices grown at large area are Rajasthan and Gujarat, while other states where commonly grown are Madhya Pradesh, Bihar, Uttar Pradesh, Odisha, Tamil Nadu, Andhra Pradesh, Karnataka and West Bengal.

Cumin (*Cuminum cyminum* L.) commonly known as zeera, safaid zeera, is the second most popular spice in the world after black pepper (Lodha and Mawar, 2014). It is the king of seed spices and is believed to be native of Syria, Egypt, Turkistan and East Mediterranean. It is extensively grown in Iran, India, Morocco, China, Southern Russia, Southern Europe and Turkey. It belongs to family Apiaceae and is valued for its aroma, medicinal and therapeutic properties (Sowbhagya, 2013; Lal *et al.*, 2014). It is an annual herbaceous plant, with a slender stem 20–30cm tall and has a diameter of 3–5cm. All the branches attain the same height, so the plant has a uniform canopy. The stem is coloured grey or dark green. The leaves are 5–10cm long alternate and filamentous. Flowers are small, white or pink, and borne in umbels. Every flower includes some green separate sharp-pointed sepals and some pink separate unequal petals. It has five stamens and bicarpel ovary that produces schizocarp diackens fruit. Diackene fruits are connected at first, but finally they part with each other. They are 5-6mm long and their diameter is 1.5-2mm, and are elongated and fusiform. Green cumin is mostly autogamous and wind has an important role in pollination of this plant. Based on numerous reports, chromosomal set of *Cuminum cyminum* is $2n=14$ in somatic cells and $n=7$ in gametic cells (Baghizadeh *et al.*, 2013).

Cumin is commonly used spice in every household in India. Seeds yield a volatile oil (2.5-4.5%), the chief constituent of which is cuminaldehyde (20-40%) which is used in perfumery and also for flavouring liquors and cordials. Seeds are largely used as a condiment and form an essential ingredient in all mixed spices and curry powder for flavouring soups, pickles and for seasoning breads and cakes (Malhotra and Vashishtha, 2008; Kumar, 2018) Seeds are also very good source of iron and manganese (Parthasarathy *et al.*, 2008) and possess antioxidant, stomachic,

astringent, anticancer, stimulant, and carminative pharmacological properties (Ravi *et al.*, 2013). Cumin flavour varies depending on the variety and its origin (Sowbhagya, 2013). The chemical composition of oil of cumin shows variations which is attributed to the difference in the geographical localities or varieties (Hanafi *et al.*, 2014).

Today, India, Iran and Turkey are the main exporters of cumin seeds in the world. India ranks first in the world in area and production of cumin. It is grown in about 5.94 lakh hectares in India with an annual production of about 3.94 lakh tones, accounting for nearly 85 per cent of world production (Kumar, 2018). In India, it is grown mainly in the states of Rajasthan and Gujarat besides Madhya Pradesh, Uttar Pradesh, Punjab and Maharashtra. Both the states together contribute more than 95% of the total country cumin production.

Different varieties of cumin released through All India coordinated Research Project are Mc-43, Gujarat Cumin 1 (GC-1), Gujarat Cumin 2 (GC-2), Gujarat Cumin 3 (GC-3), Gujarat Cumin 4 (GC-4), 5-404, RZ-19, RZ-209, RZ-223, Ac-01-167, RZ-345, RZ-341 and UC-341.

In J&K State, *Kandi* area is 811 km² which stretches between longitude 74° 21' to 75° 45' E and latitude 32° 22' to 32° 55' N covering three districts viz. Jammu, Samba and Kathua. 57 per cent of the total area of these three districts is under *Kandi* belt and it is about 10-30 km wide strip stretching from Akhnoor in the West to Kathua in the East. The upper portion of *Kandi* (above 500m) consists of low hills covered by shrubs and forest, while the lower terrain has cultivated lands and gully beds. Undulating topography, steep and irregular slopes, erodible and low water retentive soils, badly dissected terrain by numerous gullies, marginal, small and fragmented land holding in the *Kandi* area is making agriculture a non-profitable venture in the present situation of unreliable weather conditions. Cumin, which is in large demand by pharmaceutical and food industries, can be a better option for crop diversification in this area.

To introduce the species in the subtropical region of Jammu, it is imperative to study the growth and performance of the species vis-a-vis evaluation of different genotypes to identify the suitable one for this region.

For this purpose a field experiment was conducted to obtain basic information with following objectives:

- To evaluate the different genotypes of cumin for growth and yield parameters.
- Identification of superior genotype(s) for Jammu region.

Review of Literature

REVIEW OF LITERATURE

The relevant literature pertaining to the present investigation entitled “**Evaluation of Germplasm of Cumin (*Cuminum cyminum* Linn.) under Subtropics of Jammu**” is reviewed under following heads:

- 2.1 Importance of Cumin
- 2.2 Screening of germplasm
- 2.3 Production techniques of Cumin

2.1 Importance of Cumin

Cumin is the dried pale yellow seed of the herb *Cuminum cyminum*, a member of the Apiaceae family and is commonly known as Zur (Kashmir), Safaid Zeera and Zeera. It is a valuable seed spice and is one of the oldest and economically most important seed spice with medicinal properties. The origin of this plant is Egypt, but it has been largely cultivated in Arabian countries, India, China, Iran and Mediterranean area since olden times (Tiwari and Agarwal, 2004).

Cumin is liked for strong bitter taste and heavy aromatic odour and is used as a condiment and form an essential ingredient in all mixed spices and curry powder for flavouring soups, pickles and for seasoning breads and cakes. Seeds are aromatic, carminative, stimulant, stomachic, astringent and useful in diarrhoea and dyspepsia. Cumin is a very good source of iron and manganese. The by-product ark jeera after extraction of essential oil possess good medicinal properties for curing indigestion problems at home level. Volatile oil is used as flavouring agent in curries and culinary preparations of oriental character and most carefully due to its powerful odour and flavour (Malhotra and Vashishtha, 2008).

2.2 Screening of germplasm

One of the important approaches to increase the yield of any species lies with developing suitable strain by selecting genetically superior lines among the existing populations. Variability is the key factor for any selection programme. The possibility

of achieving improvement in any crop depends on the magnitude of genetic variability. The assessment of variability existing in the germplasm of a species is of great interest for conservation of genetic resources and also for broadening of genetic base of species to be exploited by plant breeders. Allard (1960) suggested that the selection should be applied mainly in the lines exhibiting high mean and variability. Families or crosses with the highest mean could be effectively utilized to identify superior segregates (Finker *et al.*, 1973). Literature pertaining to estimation of variability in *Cuminum cyminum* is reviewed as under.

Four groups of cultivars viz. tall, dwarf, pink flowered and white flowered are generally found in the species. The pink flowered variety yields better than the white flowered variety. Crop improvement work led to the release of different improved cultivars. Different varieties/genotypes of cumin which have been released by different organizations are tabulated in Table-1.

Ramavatar *et al.* (1991) reported significant variability for wilt incidence, powdery mildew, days to flowering, days to maturity, plant height, primary branches per plant, umbels per plant, umbellets per umbel, however, the range of variability was narrow for days to flowering, plant height, branches per plant, seeds per umbel and test weight in 50 lines of cumin.

Low genetic variation for seed yield was observed while evaluating 200 accessions of cumin on normal soil at All India Coordinated Spices Improvement Project, Jobner. Variability in plant height, number of branches per plant, umbels per plant, umbellets per umbel and grains per umbels were significant. Environmental effects were more pronounced for all the characters (AICSIP, 1993).

Dhayal and Bhargava (1997) evaluated nine diverse cumin genotypes under moisture stress and normal moisture conditions on the basis of drought susceptibility index and reported that moisture stress caused moderate to serve reduction in grain yield and its contributing attributes. The genotypes RS-1, UC-89, UC-209, UC-216 and UC-217 were found tolerant to moisture stress.

Table 1: The details of varieties/selections released by different organizations

S.No.	Variety	Parentage	Organization	Yield (kg ha ⁻¹)
1	S-404	Selection from local germplasm	Gujarat Agricultural University (GAU), Jagudan	350
2	MC-43	Selection from Germplasm	GAU, Jagudan	580
3	Gujarat cumin1 (GC-1)	Selection from local Germplasm (Vijayapur-5)	GAU, Jagudan	550
4	Gujarat cumin 2 (GC-2)	Pureline selection from M2 irradiated seeds of MC-43	GAU, Jagudan	620
5	Gujarat cumin 3 (GC-3)	Recurrent selection derived from W. German entry EC 232689	GAU, Jagudan	620
6	Gujarat cumin 4 (GC-4)	Natural crossing followed by selection	GAU, Jagudan	1250
7	RZ-19	Recurrent single plant progeny from collection of Ajmer	Rajasthan Agriculture University (RAU), Jobner	560
8	RZ-209	Recurrent single plant progeny from collection of Jalore	RAU, Jobner	650
9	RZ-223	Mutation breeding in UC-216	RAU, Jobner	600
10	AC-01-167-2005	Released from EC-243373	NRC Seed Spices, Ajmer	515

(Kumar, 2018)

Dhayal *et al.* (2001) conducted a laboratory experiment to identify cumin (*Cuminum cyminum* L.) genotypes tolerant to salt at germination stage at Jobner, Rajasthan. Four salinity levels having electrical conductivity of 2.61 (control), 5.17 (low), 8.10 (medium) and 12.15 (high) dSm⁻¹ were tested. There is an increase in the suppression of seed germination with increase in salinity in all the genotypes tested. The genotype UC-208 showed maximum salt tolerance followed by UC-209 and UC-218. Under normal conditions, there was 96.66 per cent to 100.00 per cent germination except in two genotypes, may be due to poor seed quality. At low salinity level, minimum germination (50%) was observed in UC-216 and maximum (100 %) in local and UC-208. At medium salinity level, the decrease in germination was more pronounced; minimum germination was observed in UC-198 (16.66%) and maximum (70.00%) in UC-208. At high salinity level, minimum germination was recorded in UC-198 (13.33%) and maximum germination in UC-208 (66.66%) followed by UC-

209 (63.33%) and UC-218 (60%) which were at par. The mean germination percentage was highest in UC-208 followed by UC-209 and UC-218, thus showing maximum salt tolerance. The results of the study indicated the existence of tolerance to salinity in cumin genotypes and also suggest the possibilities of further improvement through selection and hybridization.

Singh *et al.* (2001) worked on the variability parameters using ten genotypes of cumin under saline condition. They reported that relatively high genotypic coefficient of variation and phenotypic coefficient of variation, heritability along with high genetic advance as percentage of mean was recorded for grain yield, umbels per plant, grains per umbels and harvest index. So selection based on these traits would be effective for yield in cumin under salinity.

Bahraminejad *et al.* (2011) assessed the genetic diversity of cumin and determine the traits effective on seed yield and cuminaldehyde. Forty nine cumin ecotypes belonged to nine populations from different provinces of Iran were evaluated based on morphological and biochemical traits. Results of study indicated significant variation for all the measured traits among and within populations derived from different provinces and it was found that in Esfahan populations, the number of umbel per plant and 1000 seed weight demonstrated 59.5 per cent of linear changes in biological yield. Golestan population showed 99.6 per cent change while Yazd had almost the lowest levels of traits. It was concluded that seed yield varied significantly among different provinces ranging from 395.29–1540.28gm⁻² and cuminaldehyde from 2.02 – 3.10ml. So the high yielding genotypes with different genetic background can be recommended for cultivation and breeding programme in Iran.

Motamedi-Mirhosseini *et al.* (2011) conducted a field experiment to study the effects of drought stress on agronomic traits in cumin landraces of Iran. Nine land races (49 sub landraces) from different origins of Iran were studied. The results showed that drought stress significantly influenced number of umbels per plant, number of seed per umbel, number of seeds per plant, dry matter weight, 1000 seed weight and seed yield. There were significant differences among land races for number of seeds per plant and seed yield. The landraces of Yazd (1.15g), Southern-Khorasan (1.05g) and Pars (1.02g) had the highest seed yield per plant among evaluated landraces and it seemed that in drought stress condition number of seeds per

plant was the greatest factor that is affected by drought stress and it was suggested that cumin is a drought tolerant crop.

Rawal *et al.* (2014) carried out an experiment at Salyan, Nepal from October 2012 to April 2013 to study the performance of cumin (*Cuminum cyminum* L.) varieties at different sowing dates. The experiment was laid out in a split plot design having two factors, date of sowing as a main factor and varieties as sub-factor. The treatment combinations were replicated thrice. There were three sowing dates i.e, 15th October, 1st November and 15th November and five varieties viz. Guha-104, G-4, RZ-209, Sri Ram Gold and GC-4. Varieties Guha-104 and G-4 sown on 15th October recorded the highest seed yield 0.79 t ha⁻¹ and 0.63 t ha⁻¹, respectively. Variety RZ-209 sown on 1st November produced the lowest seed yield (0.22 t ha⁻¹). Of the tested sowing dates 15th October was more appropriate in terms of higher yield and among the different varieties.

In a research trial conducted at Ajmer, twenty germplasm lines of cumin were evaluated with two checks GC-4 and RZ-209. The mean value were recorded to be 117.86, 75.59, 30.92cm, 28.88g, 23.81, 20.62, 10.26, 5.71, 5.17 and 4.12g for days to maturity, days to 50 per cent flowering, plant height, seed yield, seeds per umbel, umbels per plant, secondary branches per plant, primary branches per plant, umbellets per umbel and test weight, respectively. Maximum variability was found for the plant height (75.42%) followed by seed yield (55.60%), umbels per plant (39.54%), seeds per umbel (21.98%), secondary branches per plant (19.35%), days to 50 per cent flowering (8.40%), test weight (7.86%), days to maturity (7.05%) and primary branches per plant (4.79%). Minimum variability of 1.70 per cent was found for umbellets per umbel (NRCSS, 2014).

Bairwa *et al.* (2015) assessed genetic variability, heritability and genetic advance in a germplasm set of 160 genotypes of cumin at Ajmer, India. The results of the study indicated presence of considerable amount of variability with highest GCV for seed yield per plant (23.8) followed by plant height (19.47), primary branches per plant (15.93) and test weight (15.64). Heritability estimates were high for seed yield per plant (0.91), plant height (0.85), days to maturity (0.81) and test weight (0.76). High heritability values coupled with high genetic advance was recorded for seed yield per plant, suggesting that phenotypic selection for this trait would be effective.

Choudhary *et al.* (2015) assessed the genetic diversity among Indian cumin cultivars by using RAPD molecular markers at Ajmer, Rajasthan. After DNA extraction, complement gene locuses were amplified by 20 RAPD primers, out of which only 15 primers showed amplification which detected polymorphism among accessions. These primers produced 1191 bands, of which 218 bands (about 18.30%) were polymorphic. Some of the primers were able to show a high level of genetic diversity while others produced a little variability. The resulting dendrogram categorized the accessions into three groups showing 53 per cent similarity. Principle Component Analysis was performed and 3 dimensions graphs using 15 primers and 55 genotypes were drawn. The Polymorphism Information Content values varies from 37 to 86 with an average of 57.26. The pair wise similarity values ranged from 0 to 0.531. The observation of molecular data reveals significant diversity among genotypes. The cultivars with diverse pattern for RAPD were suggested to be used for advance study and to select parents for inheritance or linkage group.

Meena *et al.* (2015) evaluated 140 cumin lines collected from various places of country for 19 agro-morphological characters . The germplasm set showed ample diversity for both qualitative and quantitative traits. Among the qualitative traits studied, maximum diversity was recorded for early plant vigour (82 under very good category, whereas 18 under poor category), plant growth (85 lines showed semi erect behavior), stem pigmentation, stem characters, nature of branching, foliage density, umbel compactness, arrangement of umbellate and seed colour. Variability with high ranges were observed for quantitative traits. Seed yield show significant positive correlation with umbels per plant.

In an evaluation of station trial comprising of 10 genotypes and two checks RZ-209 and GC-4 of cumin, 40 entries were tested in wilt sick plot. Ample amount of variability was observed for growth behaviour, plant height, number of umbels and test weight. Variation was also high for plant architecture, plant height, biomass, number of umbels and test weight, whereas, variation for umbellets per umbel was found very low. Based on the field performance, genotypes CE-13, CE-15, CE-17, CE-8 and CE-4 were found promising (NRCSS, 2015).

Safari *et al.* (2015) conducted an experiment to study the effects of drought stress on important agronomic traits of 49 cumin ecotypes collected from different

regions of Iran and evaluated under drought stress and non-stress conditions during 2012 and 2013. Number of umbels per plant, number of seeds per umbel, seed weight, harvest index and seed yield were recorded. The combined analysis of variance showed significant differences among genotypes, among environments and the genotypes x environment interactions. The low irrigation (soil water supply at 30% field capacity) after flowering stage decreased the value of all traits but to the different extent. The highest adverse effect was on the seed yield. In average of both years, water shortage decreased seed yield about 33.6 per cent. Moreover, 1000 seed weight was affected by the environmental condition at the lowest extent (3.8%). Also, based on means comparison, the highest and the lowest seed yield on the average of two years belonged to ecotypes from North Khorasan-Baneh in the normal condition (105.07gm^{-2}) and North Khorasan-Esfaraieen under low irrigated condition (20.53gm^{-2}), respectively. Considering all evaluated traits under both conditions, ecotypes from North-Khorasan (Baneh) and Semnan (Shahmirzad) were recognized as best performing ecotypes.

Jat and Singh (2016) evaluated twenty genotypes of cumin in normal, salinity and moisture stress conditions for nine quantitative traits to estimate the nature and magnitude of variability, heritability (bs). Results of the study revealed that the highest mean value of plant height (25.33 cm), umbels plant^{-1} (10.96), umbellets umbel^{-1} (4.54), seeds umbel^{-1} (24.09), biological yield (24.00g) and seed yield (13.09g) was observed in normal condition followed by moisture stress and saline condition whereas days to 50 % flowering (75.28), branches per plant (21.38), 1000 seed weight (3.70g) shows highest value in moisture stress condition followed by normal and salinity condition. Analysis of variance indicated significant variability for all the traits. The genetic advance was found high for seed yield, biological yield, branches plant^{-1} and umbels plant^{-1} in stress condition while high genetic advance for plant height, biological yield and seed yield in normal condition. Significant and positive correlation of seed yield was observed with seeds plant^{-1} and biological yield in stress condition but in normal condition, seed yield had positive correlation with branches plant^{-1} .

Meena *et al.* (2016) conducted a research trial at Ajmer in Rajasthan and reported high estimates of GCV for secondary branches (25.62%) followed by seed yield plot^{-1} (21.85%) and umbel plant^{-1} (16.89%). High heritability were obtained for

primary branches (48.91%), seeds umbellate⁻¹ (43.39%), seed umbel⁻¹ (41.49%) and moderate for umbellate umbel⁻¹ (37.85%), secondary branches (37.84%), umbels plant⁻¹ (37.72%), plant height (37.55%), seed yield plot⁻¹ (10.61%), test weight (5.36%) which clarified that they were least affected by environmental modifications and selection based on phenotypic performance would be reliable. High estimates of genetic advance was realized for secondary branches (32.46%), umbel plant⁻¹ (21.36%), primary branches (19.19%) and moderate for seed yield plot⁻¹ (14.66 %), seeds umbel⁻¹ (12.23%). It was concluded that primary branches, secondary branches and seeds per umbel were the important components in selection for genotypes with higher seed yield per plant.

11 test entries of cumin were evaluated in a station trial at Ajmer, Rajasthan for yield and yield contributing traits along with two checks RZ-209 and GC-4. It was found that entry CE-15 showed the highest yield of 4.9g followed by CE-8 (4.7g), CE-6 (4.7g), CE-13 (4.6g), CE-7 (4.6g), GC-4 (4.2g) and CE-14 (4.2g). Maximum variability of 18.6 per cent was found for the character seed yield per plant. In the same trial different germplasm lines were assessed for *Fusarium* infection and the entries SPS-13-69, SPS-13-13, SPS-13-40 showed higher survival percentage (NRCSS, 2016).

Mortazavian *et al.* (2018) conducted an experiment in Iran in which forty-nine diverse cumin ecotypes were tested under normal and water stress conditions. The experiment was conducted under two different irrigation regimes of normal irrigation and mid/late season water stress i.e., during flowering. Twelve drought tolerance indices were calculated based on seed yield under drought and irrigated conditions. Yield under stress and non-stress conditions was significantly and positively correlated with Geometric Mean Productivity, Stress Tolerance Index, Harmonic Mean, Drought Resistance Index, modified Stress Tolerance Index in normal irrigation, modified Stress Tolerance Index in stress irrigation, Stress Non-stress Production Index and Stress Tolerance Score. PCA and cluster analysis were followed to reveal the relationship among different indices. On the basis of mean yield and drought tolerance indices, ecotypes from Maneh (Northern Khorasan), Shahmirzad (Semnan) and Rafsanjan (Kerman) were identified as the best.

Three station trials in cumin were conducted in which 15 entries in first trial, 12 in each second and third trial along with two checks GC-4 and RZ-209 were evaluated. The results of the first trial showed that entries GP-3, GP-7, GP-39, GP-19, and GP-6 recorded higher yield of 53.33g, 50.77g, 43.27g, 40.17g and 36.67g, respectively while higher test weight was recorded in GP-19 (4.18g). In 2nd trial, CE-15 (77.07g) and CE-14 (66.9g) entries were superior to GC-4 (60.33g) in terms of seed yield per plant. In trial 3rd AC-WMT-16-40 and AC-WMT-16-73 recorded higher seed yield (131.17g, 107.33g) and resistance/ tolerance as compared to check varieties (NRCSS, 2019).

2.3 Production techniques of Cumin

Cumin thrives well in tropical and subtropical climate. Sandy loam or loamy soil is supposed to be the best for its successful production. It is propagated through seed (seed rate 90kg ha⁻¹) and sowing is taken up between 15 November and late December (in Gujarat and Rajasthan). Line sowing is practised at a spacing of 30 × 15cm. First irrigation is given just after sowing, second 7-8 days after sowing. Afterward, irrigation is given at an interval of 12-20 days. The crop matures after 100-110 days after sowing and the average yield is about 5.5qha⁻¹ (Kumar, 2018).

Azizi and Kahrizi (2008) studied the effects of nitrogen fertilizer and plant density on the growth, seed yield, quantity and quality of essential oil of cumin under the climatic conditions of Lorestan province of Iran. Nitrogen as main factor (0, 2.5, 5.0 and 10.0gm⁻²) and plant density as subsidiary factor (80, 120 and 160 plants m⁻²) were applied. The results showed that the highest umbels per plant (42.34), seeds per umbel (9.78) and biological yield (22.31g) were related to the 2.5gm⁻² nitrogen fertilizer and 120 plants m⁻² treatment and the highest value of variable include weight of thousand seeds (4.9g), seed yield (108.4gm⁻²) and percentage of seed essential oil (2.89%). They suggested the temperate location as the most suitable for cumin growing and production.

Ghorbani *et al.* (2010) conducted two field experiments in Iran in order to evaluate the effects of planting date, method and date of weed control on yield and yield components of cumin during 2006-2007. Treatments included planting dates (30 December, 20 January and 30 February), weeding dates (first true leaf, start of branching and beginning of flowering stages) and weed control methods (hand

weeding, fire treatment and control). The results of the study showed significant differences between different sowing dates as the highest yield was in 30th December and lowest in 30th February sown seeds, the delay in sowing dates decreased number of seed and biological yield. Significant differences were also seen in start of branching stage, branching stage and first true leaf stage in different times of weed control. The highest yield was considered in the beginning of branching. It also showed significant differences between hand weeding, control and fire treatments. The highest seed and biological yield was obtained in hand weeding methods.

Ahmadian *et al.* (2011) conducted an experiment in Iran to study the effects of water stress and manure application on yield components, oil percentage and its main constituents in cumin. Treatments including irrigation intervals (I₁: two times irrigation, I₂: three times irrigation and I₃: four times irrigation i.e, irrigation in germination, seedling, flowering and seed filling stages) and manure application (F₁: without manure application, F₂: 20tha⁻¹ manure application). Three irrigation times (I₂) with manure treatment F₂ produced the highest number of umbels per plant (31.05), seed yield (493kg ha⁻¹), biological yield (926kg ha⁻¹) and the lowest 1000-seed weight (2.34g) and number of seed per umbel (12.65). The chemical composition of the essential oil was examined by GC and GC-MS and they were significantly affected by water stress and manure. Three irrigation times with manure treatment F₂ caused the highest amount of cuminaldehyde and *p*-cymine and the lowest of *β*-pinene, *γ*-terpinene and *α*-pinene.

Kahrizi *et al.* (2011) conducted an experiment to study the effects of nitrogen fertilizer and plant density on quantitative relationships between yield and yield components and essential oil in cumin under three different climate testing sites (cold, tropical and moderate climate locations) in western Iran. Plant density (80, 120, 160 plant m⁻²) and Nitrogen fertilizer (0, 25, 50, 100 kg ha⁻¹) were main and subsidiary factors, respectively. Maximum yield (1275 kg ha⁻¹) and essence (2.78%) were obtained at 100kg nitrogen ha⁻¹ and 160 plant m⁻² in moderate location. Analysis of variance for testing contrasts of plant density and nitrogen fertilizer showed significant linear relationship between nitrogen fertilizer and yield components. Significantly positive correlations were also observed between yield and number of seeds per plant, number of umbels per plant, number of seeds per umbel, thousand

seed weight and biological yield at tropical location. To gain maximum seed and essence in cumin, moderate location was recommended.

Rahimi (2012) conducted an experiment in research field of Vali-e-Asr University of Rafsanjan to investigate seed pre-treatment and irrigation interval effects on quantity and quality yield of the primed seeds of cumin. The results of the study indicated that the seed yield was significantly decreased with increasing of irrigation intervals which was related to more decrease of umbel number and seed number per umbel. The highest umbel number in plant (14.62) and seed number per umbel (13.16) were obtained in seed pretreatment of -0.3 Mpa PEG, and in 5 and 7 day irrigation intervals. Totally, the highest seed yield (628.7 kg ha^{-1}) was obtained in seed pre-treatment of -0.3 Mpa PEG and 5-day irrigation interval and the highest essence content (3.62%) was obtained in pre-treatment of distilled water and 7-day irrigation interval.

Sharma *et al.* (2013) conducted a field survey in the cumin-growing districts of Rajasthan and Gujarat from rabi 2007-08 to rabi 2011-12 to know the status of cumin diseases on farmers' fields. The major cumin diseases observed were wilt (0-60%), blight (0-80%), and powdery mildew (0-54%) in moderate to severe form. The information collected revealed that wilt and blight diseases were wide spread and occurred in Ajmer, Nagaur, Barmer, Jalore, Jodhpur, Jaisalmer, Pali, districts of Rajasthan and Banaskantha and Patan districts of Gujarat. Whereas, powdery mildew appearance was observed in few districts of both the states. Phyllody was observed in Barmer and Jalore districts in traces. Few fields were also infested with parasitic plant *Orobanche* in Nagaur and Jodhpur districts of Rajasthan. The two air born diseases powdery mildew and blight are highly weather dependent, hence prophylactic management strategy is very much needed to combat them.

Heidari and Sadeghi (2014) conducted a study to investigate the effectiveness of GA_3 and temperature regimes as seed priming strategies on the seed germination parameters of cumin. Cumin seeds were treated with different GA_3 concentrations (0, 100, 200 and 400 ppm) and then were placed in growth chamber at 20, 25, 30 and 35 °C. Overall, the results suggested that the 400 ppm of GA_3 in combination with 25 °C temperature showed the better seed germination and seedling growth characters in cumin seed.

Mehta *et al.* (2014) studied growth, profitability and productivity of cumin as influenced by irrigation and nutrient levels with varying crop geometry. Three irrigation levels (12, 15 and 18-day interval) in main plot, nutrient levels (N and P₂O₅ each of 20 + 10, 30 + 20 and 40 + 25 kg ha⁻¹, respectively) in sub-plot and crop geometry (20 cm × 10 cm, 25 cm × 10 cm and 30 cm × 10 cm) in sub-plot were studied. The results of the study showed that application of irrigation at 18-day interval with 30 kg N + 20 kg P₂O₅ ha⁻¹ at 25 cm × 10 cm crop geometry was found better for realizing higher yields, net return and profitability in cumin production.

Jami and Mehraban (2015) estimated the outcomes of different levels of drought stress and salicylic acid on quantitative as well as qualitative performance of cumin herb. The characteristics measured and investigated are height of plant, number of seeds per umbel, number of umbels per plant, grain yield and weight, grain yield per plot and wet and dry forage yield as well. Results, displayed the dryness and foliar application of salicylic acid's influence on the most of the characteristics. On one hand, dryness caused a negative impact on these attributes and on the other hand, foliar application of salicylic acid has visibly improved these features.

Shakeri *et al.* (2015) examined the effect of sowing dates and seeding level on yield and yield components of cumin in Birjand, Iran in 2009-2010. There were four sowing dates (December 9, January 8, February 7 and March 9) and three seeding levels (15, 30 and 45 kg ha⁻¹). The results showed that the delay in sowing from January 8 to March 9 decreased seed and biological yields by 59.04 and 63.01 per cent, respectively. In addition, the delay in sowing from January 8 to February 7 and March 9 significantly decreased seed yield of single plant by 50.7 and 70.7 per cent, respectively. Increase in seeding level from 15 to 45 kg ha⁻¹ decreased seed yield by 4 per cent, but biological yield increased by 13.28 per cent. Sowing date of January 8 with the seeding level of 15-30 kg ha⁻¹ was recommended for the cultivation of cumin in Birjand, Iran.

Singh (2015) studied the effect of irrigation techniques and planting methods on yield and yield components of cumin under semi-arid conditions of Rajasthan in India. Three irrigation techniques viz., surface irrigation, drip and micro sprinkler in main plot and three sowing methods viz., flat bed, raised bed 75 cm (normal bed) and wider raised bed 150 cm in sub plots were applied. Seed yield was significantly

influenced by irrigation methods and land configuration. Irrigation with drip gave higher seed yield followed by micro sprinkler and lowest with surface (flood) irrigation. Among the land configuration, sowing of 3 rows of cumin on raised beds (75 cm) not only enhanced the yield but also improved the water productivity in cumin.

Birla *et al.* (2016) conducted field experiment at Mandsaur (Madhya Pradesh) to study the weed management practices in cumin. Twelve weed management treatments were laid in randomized block design with three replications. Weed free treatment recorded significant maximum growth and yield attributes of cumin followed by oxadiargyl @ 0.06 kg/ha followed by two hand weeding at 40 and 60 days after sowing. Similarly, significant maximum seed yield (595 kg/ha), straw yield (900 kg/ha) and harvest index (39.7%) was observed with oxadiargyl @ 0.06 kg/ha as pre-emergence followed by two hand weeding at 40 and 60 days after sowing. Maximum weed population was measured in case of weedy check, which was followed by hand weeding (40 DAS) at all the growth stages of cumin. Application of oxadiargyl @ 0.06 kg/ha as pre-emergence followed by two hand weeding at 40 and 60 days after sowing may be practiced for higher yield of cumin.

Kunapara *et al.* (2016) conducted a field experiment to assess the conjugate impact of three irrigation regimes (0.6 IW/ETc, 0.8 IW/ETc and 1.0 IW/ETc) and three lateral spacing (0.60 m, 0.70 m and 0.80 m) on productivity of cumin. The results revealed that higher seed yield, plant height and dry matter of 1344.17 kg ha⁻¹, 36.42 cm and 2365 kg ha⁻¹, respectively were recorded at 0.8 IW/ETc with lateral spacing of 0.6 m compared to other treatments. Highest water use efficiency (5.58 kg/ha/mm) was observed at 0.6 IW/ETc with 0.60 m lateral spacing. Highest B:C ratio (2.27) observed at 0.8 IW/ETc with lateral spacing 0.6 m as compared to other treatments.

Rezaeieh *et al.* (2016) evaluated effects of Zn on vegetative growth, grain yield and its components on cumin genotypes. The results of the study revealed highest amount of grain yield and essential oil (3.64 %) by using 3 kg ha⁻¹ Zn application. Root length (3.59cm) and total dry matter (2.71 kg m⁻¹), had the most positive direct effects and in contrast plant height (-1.63), number of branches per plant (-2.33) had negative direct effect on grain yield. Number of branches (3.44)

through root length and plant height (2.52) through total dry matter had maximum positive indirect effects on grain yield. Total dry matter through plant height (-1.51), oil yield (-1.18), and root length through number of branches per plant (-2.23) had maximum negative indirect effect on grain yield of cumin genotypes. It was concluded from the study that Zn applications had proven effective in increasing the productivity of grain, oil yield and other studied factors among all cumin genotypes.

Yadav *et al.* (2018) conducted an experiment at SKRAU, Rajasthan, Bikaner during Rabi to find out the insect pest attacking cumin crop sowing at different dates to determine the optimum dates of sowing. Five sowing dates viz. 25th October, 5th November, 15th November, 25th November and 5th December at 10 days intervals were considered as different treatments to find out the pest incidence and effect on grain yield. The results of the study showed that the incidence and population fluctuation of insect pest of cumin was very much dependent on the prevailing climatic conditions of the cropping season. The late sown (5th December) crops received higher pest infestation followed by crop sown 25th November. Hence, for ensuring higher yield with less insect pest infestation, cumin should be sown within the period of October 25 to December 5 and the best date of sowing is November 5.

Material and Methods

MATERIAL AND METHODS

Studies on “**Evaluation of Germplasm of cumin (*Cuminum cyminum* Linn.) under Subtropics of Jammu**” were carried out in the Agroforestry experimental farm, Sher-e- Kashmir University of Agricultural Sciences and Technology of Jammu during the year 2018-19. The details of the experimental site, experimental materials used and the methodology followed during the course of investigation are given here under the following headings:

- 3.1 Experimental site
- 3.2 Experimental details
- 3.3 Cultural practices
- 3.4 Experimental observations
- 3.5 Statistical analysis

3.1 Experimental site**3.1.1 Location**

The experimental site is situated in subtropical Jammu region of Jammu and Kashmir State at an altitude of 332 m above mean sea level between 32°40' N latitude and 74°58' E longitude.

3.1.2 Climate and weather conditions

The experimental site experiences hot dry summers, humid rainy season and cold winter months. The average annual rainfall at the site is about 1000 – 1200 mm with 75 - 80 per cent of which is received during July to September and rest 20-25 per cent during winter months of December to February. The maximum temperature rises upto 45 °C during May to June and minimum falls to 1 °C during winter. The weekly weather data recorded at Meteorological Observatory of SKUAST-Jammu, Chatha, for the year 2018-19 (November 2018- April 2019) is given in Fig.1.

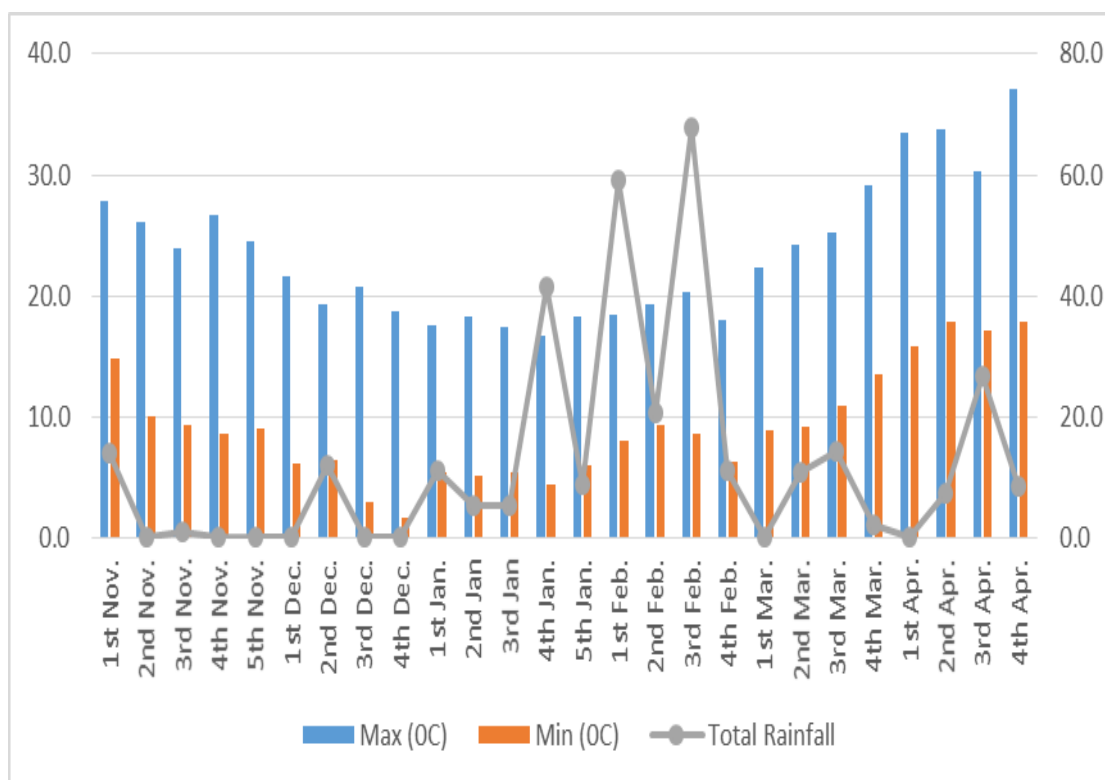


Fig. 1 Weekly meteorological data w. e. f. November, 2018 to April, 2019

3.1.3 Soil characteristics

For physico-chemical analysis of the soil, five composite soil samples were collected from the experimental site at a depth of 0-15 cm before planting, following the procedure of random sampling (Peterson and Calvin, 1965). The collected samples were mixed thoroughly, air dried, grinded, sieved and kept in cloth bags for subsequent analysis. The soil was sandy loam in texture. The test values for different parameters after analysis were presented in Table-2.

Table 2: Chemical characters of the experimental site at the beginning of the experiment

S.No.	Parameters	Test value	Method employed
1	Organic Carbon (g/kg)	4.10	Rapid titration method (Walkey and Black, 1934)
2	Available Nitrogen (kg/ha)	242.25	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
3	Available phosphorus (kg/ha)	15.02	Olsen <i>et al.</i> (1954)
4	Available potassium (kg/ha)	134.85	Merwin and peach, 1951

3.2 Experimental details

3.2.1 Experimental material and design

The experiment was laid out in Randomized Block Design with eight genotypes which were replicated thrice. The field experiment was conducted during the rabi season of 2018-2019. The plot size was 1.5x1.0m² with spacing of 30x5cm² in each plot. The experimental material comprised of seeds of 8 genotypes which were procured from Sri Karan Narendra Agriculture University, Jobner, Rajasthan and are listed below.

S.No.	Variety/ Genotype
1	GC- 4
2	RZ-19
3	RZ-209
4	RZ-223
5	RZ-341
6	RZ-345
7	UC-231
8	UC-198

3.3 Cultural Practices followed

3.3.1 Field preparation and sowing of seeds

Raised beds of 1 m x 1.5 m size were prepared in the field. At the time of sowing, basal dose of DAP, Urea and Ammonium phosphate at the rate of 130.4, 101.15 and 66.66 kg per ha⁻¹, respectively was added. Seeds were first treated with Carbendazem and Mencozeb at the rate of 2 g/kg of seed before sowing. Seeds were sown in lines which are 30cm apart on 16th November, 2018. Later on thinning of seedlings was done to maintain a spacing of 5cm between the plants. All the cultural and plant protection practices were followed from sowing till the harvesting of cumin.

3.4 Characters studied

Observations were recorded individually on 15 randomly selected plants per treatment (five plants per replication). The detailed procedure adopted for recording observations in each characters is described as under:

3.4.1 Germination percentage (%)

Germination percentage was calculated by dividing total number of seeds germinated by total number of seeds sown and multiplied by 100. It was calculated by using the following formula:

$$\text{Germination(\%)} = \frac{\text{Total seeds germinated (when no further germination occurred)}}{\text{Total number of seeds}} \times 100$$

3.4.2 Survival percentage (%)

Survival percentage was calculated by dividing total number of plants survived by total number of the plants in bed and multiplied by 100.

3.4.3 Plant height (cm)

Plant height was measured with the help of wooden scale from the level of ground to the tip of the umbel at harvesting stage for all the genotypes and was recorded as mean of five plants for each bed.

3.4.4 Number of branches per plant

Total number of branches per plant emerging directly from the main stem was counted at maturity from the five tagged plants of each genotype and average value per plant was calculated.

3.4.5 Number of umbels per plant

Total number of matured seed bearing umbels per plant was counted from each of the five selected plants at the time of maturity and mean was calculated by taking average of five plants.

3.4.6 Number of seeds per umbel

Total number of seeds from main umbel of randomly selected 5 plants were counted and average of five plants was taken as mean value.

3.4.7 Number of seeds per plant

Total number of seeds per umbel was counted and then multiplied by total number of umbels per plant and the average of five plants was taken as mean value.

3.4.8 1000 seed weight (g)

Random sample of 250 seeds was drawn from the produce of each plot and weighed on electronic balance which were used to obtain 1000 seed weight in grams.

3.4.9 Seed yield per plant (g)

The seeds present in all the umbels on a plant were pooled together and total weight was recorded in grams and reported as mean value.

3.4.10 Seed yield per plot (g)

Seed yield per plot was calculated by multiplying the number of plants survived with seed yield per plant.

3.4.11 Estimated seed yield per hectare (kg ha⁻¹)

The estimation of seed yield was done by taking the per plant yield of seed and multiplying it with the number of plants per hectare (1m x 1.5m spacing) and was reported in kilograms per hectare.

3.5. STATISTICAL ANALYSIS

The data pertaining to various characters were statistically analyzed using ANOVA. A variance analysis was computed for each variable and covariance analysis for each pair of variables. The mean values of 15 randomly selected plants from each genotype were used for statistical analysis. The statistical techniques followed are as under:

3.5.1 Analysis of variance

The statistical analysis for each character was carried out on mean values. The data was subjected to analysis of randomized block design as suggested by Pillai and Sinha (1968). The ANOVA table was set up as:

Source of variation (F)	d.f.	Mean sum of squares	Variance ratio
Replication	(r-1)	Mr	Mr/Me
Treatment	(t-1)	Mt	Mt/Me
Error	(r-1) (t-1)	Me	

Where,

r = Number of replications

t = Number of treatments

Mr = replication mean square

Mt = treatment mean square

Me = error mean square

The standard error and critical differences were calculated as follows

$$S.E (d) \pm = \frac{\sqrt{2 \times Me}}{r}$$

$$C.D. \text{ at } 5\% = S.E (d) \times t_{5\%} \text{ (at error degree of freedom)}$$

Where,

S.E (d) = Standard error of difference

C.D. at 5% = Critical difference at 5 per cent level of significance

3.5.1.1 Variability estimation

In case of evaluation of different genotypes of *Cuminum cyminum*, the variability estimates for different characters along with coefficient of variability were calculated. The estimates consist of heritability, genetic advance and genetic gain were also carried out. Observations for variability, genetic estimates and correlation studies were limited to five selected plants in each replications. The components of genotypic, phenotypic and error variance were calculated as follows:

$$V_g = \frac{Mt - Me}{r}$$

$$V_p = V_g + V_e$$



Fig. 2 General view of experimental field



Fig. 3 Seeds of different genotypes of cumin



Fig. 4 Field preparation and layout of trial



Fig. 5 Seed sowing in the field



Fig. 6 Seed germination stage of the crop

$$V_e = M_e$$

Where,

V_g = genotypic variance

V_p = phenotypic variance

V_e = error variance

3.5.1.2 Coefficient of variability

Phenotypic, genotypic and environmental coefficients of variability were carried out by formulae suggested by Burton and DeVane (1953).

$$PCV(\%) = \frac{\sqrt{V_p}}{\bar{X}} \times 100$$

$$GCV(\%) = \frac{\sqrt{V_g}}{\bar{X}} \times 100$$

$$ECV(\%) = \frac{\sqrt{V_e}}{\bar{X}} \times 100$$

Where,

PCV = phenotypic coefficient of variability

GCV = genotypic coefficient of variability

ECV = environmental coefficient of variability

$\bar{X}$ = population mean of a particular character under study

3.5.1.3 Heritability

Heritability in percentage in broad sense was calculated by the formula suggested by Burton and DeVane (1953) and Johnson *et al.* (1955).

$$H(\%) = \frac{V_g}{V_p} \times 100$$

Where,

H = heritability in broad sense

V_p = phenotypic variance

V_g = genotypic variance

3.5.1.4 Genetic advance

The expected genetic improvement was calculated as per the formula suggested by Burton and DeVane (1953) and Johnson *et al.* (1955).

$$\text{Genetic advance} = \frac{V_g}{V_p} \times \sqrt{V_p} \times k$$

Where,

V_p = phenotypic variance

V_g = genotypic variance

K = selection difference at 5% selection intensity. The value of k is 2.06 (Allard, 1960)

3.5.1.5 Genetic gain

Genetic gain was also expressed in percent of population mean and was calculated by following method suggested by Johnson *et al.* (1955) as under:

$$\text{Genetic gain (\%)} = \frac{\text{Genetic advance}}{\bar{X}}$$

3.5.2 Correlation studies

If the change in one variable affects the change in the other variable, the variables are said to be correlated. In other words, the systematic interrelationship between the variables is termed as correlation. The index of the degree of relationship between two continuous variables is known as correlation coefficient which can be calculated by following formula:

$$r = \frac{\text{Cov}(x,y)}{\sigma_x \cdot \sigma_y}$$



Fig.7 Application of fungicide in the field



Fig. 8 Field view after germination



Fig. 9 Thinning and weeding in crop



Fig.10 General view of the trial

Experimental Results

EXPERIMENTAL RESULTS

The present investigation entitled “**Evaluation of Germplasm of Cumin (*Cuminum cyminum* Linn.) under Subtropics of Jammu**” was conducted at Agroforestry farm, SKUAST Jammu, Chatha during rabi season of 2018-2019. The data recorded on various parameters was analyzed and obtained is presented under different sub-headings with appropriate figures and tables.

- 4.1 Mean performance of growth and yield attributes of different genotypes
- 4.2 Estimate of variability and genetic paramaters
- 4.3 Correlation studies

4.1 Mean performance of growth and yield attributes of different genotypes

Eight genotypes of *Cuminum cyminum* procured from Sri Karan Narendra Agriculture University (SKNAU), Jobner, Rajasthan were evaluated for their effect on qualitative and quantitative parameters. From the analysis of variance, it was clear that the genotypes differed significantly from each other with respect to germination percentage (%), survival percentage (%), number of branches per plant, number of umbels per plant, number of seeds per umbel, number of seeds per plant, seed yield per plant (g), seed yield per plot (g), estimated seed yield (kg ha⁻¹) and ANOVA is appended at Appendix I. The data of the observed mean values of these characters is presented in Tables 3 and 4 and results are described as under:

4.1.1 Germination percentage (%)

The scrutiny of the data given in Table 3 divulged that germination percentage varied significantly among all the genotypes. Maximum germination of 81.98 per cent recorded in genotype RZ-209 was statistically at par with germination of 74.37 per cent recorded in genotype GC-4. The value of germination percentage observed in GC-4 (74.37%) was also statistically at par with the genotypes RZ-223 (67.05%) and RZ-19 (62.38%). Genotypes RZ-223 (67.05%), RZ-19 (62.38%) and UC-198 (61.29%) were also statistically at par with each other. Despite RZ-345 genotype

recorded the minimum germination of 48.60 per cent but was at par with RZ-341 (56.01%) and UC-231 (57.41%).

4.1.2 Survival percentage (%)

A perusal of the data showed significant variation amongst all the genotypes. Maximum survival percentage observed in genotype GC-4 (12.33%) was statistically alike to survival percentage recorded in genotypes RZ-209 (11.67%) and RZ-223 (9.67%). Genotypes UC-231 and RZ-19 recorded similar survival percentage of 8.00 per cent, however, they were statistically at par with UC-198 (7.33%), RZ-341 (6.33%) and RZ-345 (5.67%). Whereas, minimum survival percentage of 5.67 per cent was recorded in genotype RZ-345.

4.1.3 Plant height (cm)

A critical analysis of the data revealed that the genotypes did not differ significantly among themselves for plant height. However, maximum plant height of 30.31cm was observed in genotype RZ-223 followed by 30.13cm (GC-4), 29.99cm (RZ-209), 29.19cm (UC-198), 28.31 cm (UC-231), 28.27cm (RZ-19) and 26.47cm (RZ-341). Minimum plant height of 25.59 cm was recorded in genotype RZ-345.

4.1.4 Number of branches per plant

Significant variation was found among different genotypes for number of branches per plant. Genotype GC-4 recorded maximum number of branches per plant (3.47) which was followed by RZ-209 (3.33), RZ-223 (3.23), RZ-19 (3.13) and UC-198 (2.93) but all were statistically at par with each other. Minimum number of 2.23 branches per plant was recorded in genotype RZ-345 but was at par with genotype RZ-345 (2.23), RZ-341 (2.42), UC-231 (2.66) and UC-198 (2.93).

4.1.5 Number of umbels per plant

Data in the Table 3 indicated that number of umbels per plant varied significantly amongst all the genotypes. Maximum number of umbels per plant (10.91) registered in GC-4 was statistically at par with number of umbels recorded in genotype RZ-209 (9.62). Genotype RZ-209 (9.62) was also statistically at par with genotypes RZ-223 (8.32), RZ-19 (7.77) and UC-198 (7.66). Genotype RZ-345 recorded minimum number of umbels per plant (6.61) which was statistically at par

with genotypes RZ-341 (6.88), UC-231 (7.12), UC-198 (7.66), RZ-19 (7.77) and genotype RZ-223 (8.32).

4.1.6 Number of seeds per umbel

Data in Table 4 revealed that maximum number of seeds per umbel (28.79) observed in genotype GC-4 was statistically at par with number of seeds per umbel of 25.14 and 23.98 registered in RZ-209 and RZ-223, respectively. RZ-19 (21.66) and UC-198 (18.87) recorded statistically similar values for number of seeds per umbel. Minimum number of seeds per umbel (11.20) recorded in RZ-345 was at par with genotypes RZ-341 (13.33) and UC-231 (15.89).

4.1.7 Number of seeds per plant

A critical analysis of the data revealed that maximum number of seeds per plant was recorded in genotype GC-4 (313.25). Genotypes RZ-209 (240.20) and RZ-223 (200.57) were statistically at par with each other for this character. Genotype RZ-223 (200.57) was statistically alike to UC-198 (145.38) and RZ-19 (169.84). Genotype RZ-345 recorded the minimum number of seeds per plant (74.95) and was at par with UC-231 (113.78) and RZ-341 (90.92).

4.1.8 1000 seed weight (g)

The data in Table 4 revealed that the genotypes did not differ significantly among themselves for 1000 seed weight. However, maximum 1000 seed weight of 3.12g was observed in genotype GC-4 followed by RZ-209 (3.02g), RZ-19 (3.00g), RZ-223 (2.99g), UC-198 (2.99g), UC-231 (2.97g) and RZ-341 (2.95g). Minimum 1000 seed weight of 2.82g was observed in genotype RZ-345.

4.1.9 Seed yield per plant (g)

Significant variation was found among different genotypes for seed yield per plant. GC-4 genotype registered maximum seed yield per plant (0.98g) followed by genotypes RZ-209 (0.73g) and RZ-223 (0.60g). However, genotypes RZ-209 (0.73g) and RZ-223 (0.60g) were statistically at par with each other. Minimum seed yield per plant of 0.21g was recorded in RZ-345 but was statistically alike to RZ-341 (0.25g) and UC-231 (0.33g). Genotypes RZ-19 (0.53g) and UC-198 (0.45g) were also statistically alike to each other.

4.1.10 Seed yield per plot (g)

A critical analysis of data revealed that seed yield per plot of 11.61g recorded in genotype GC-4 was significantly higher than all other genotypes and was followed by genotype RZ-209 (8.57g) and RZ-223 (5.45g). RZ-19 (3.79g), UC-198 (3.52g) and UC-231 (2.47g) were statistically at par with each other. Minimum seed yield per plot recorded in genotype RZ-345 (1.11g) was at par with RZ-341 (1.64g), UC-231 (2.47g), UC-198 (3.52g), RZ-19 (3.79g) and RZ-223 (5.45).

4.1.11 Estimated seed yield (kg ha⁻¹)

Data in Table 4 indicated that estimated seed yield (kg ha⁻¹) varied significantly amongst all genotypes. GC-4 recorded maximum estimated seed yield of 77.42kg followed by RZ-209 with estimated seed yield of 57.10kg and RZ-223 (36.36kg) but all were statistically different. RZ-19 (25.26kg) and UC-198 (23.44kg) were statistically alike for this parameter. The minimum estimated seed yield of 7.42kg was registered in genotype RZ-345 which was similar to the seed yield recorded in genotypes UC-231 (16.49kg) and RZ-341 (10.93kg).

4.2 Estimation of variability and genetic parameters

The mean value of eight genotypes of *Cuminum cyminum* for various characters is presented in Table 4, while, general mean, range, variance, coefficient of variation, heritability, genetic advance and genetic gain for different characters are given in Table 5.

The estimate of coefficients of variation (GCV and PCV) were found to be high for seed yield per plot followed by seed yield per plant, number of seeds per plant, number of seeds per umbel and survival percentage.

High estimates of heritability were observed for the characters namely seed yield per plot followed by seed yield per plant, number of seeds per plant, number of seeds per umbel, germination percentage and survival percentage.

The highest estimate of expected genetic advance was recorded for number of seeds per plant. Highest genetic gain was recorded for number of seeds per plot followed by seed yield per plant, number of seeds per plant and number of seeds per umbel.

Table 3 Mean performance of growth parameters in different genotypes

Genotypes	Germination %	Survival percentage (%)	Plant height (cm)	Number of branches plant⁻¹	Number of umbels plant⁻¹
RZ-341	56.01	6.33	26.47	2.42	6.88
RZ-345	48.60	5.67	25.59	2.23	6.61
GC-4	74.37	12.33	30.13	3.47	10.91
RZ-223	67.05	9.67	30.31	3.23	8.32
UC-231	57.41	8.00	28.31	2.66	7.12
RZ-209	81.98	11.67	29.99	3.33	9.62
UC-198	61.29	7.33	29.19	2.93	7.66
RZ-19	62.38	8.00	28.27	3.13	7.77
CD 0.05	12.57	2.95	NS	0.75	2.31

Table 4 Mean performance of yield parameters in different genotypes

Genotypes	Number of seeds umbel⁻¹	Number of seeds plant⁻¹	1000 seed weight (g)	Seed yield plant⁻¹ (g)	Seed yield plot⁻¹ (g)	Estimated seed yield (kg/ha)
RZ-341 RZ-341	13.33	90.92	2.95	0.25	1.64	10.93
RZ-345	11.20	74.95	2.82	0.21	1.11	7.42
GC-4	28.79	313.25	3.12	0.98	11.61	77.42
RZ-223	23.98	200.57	2.99	0.60	5.45	36.36
UC-231	15.89	113.78	2.97	0.33	2.47	16.49
RZ-209	25.14	240.20	3.02	0.73	8.57	57.10
UC-198	18.87	145.38	2.99	0.45	3.52	23.44
RZ-19	21.66	169.84	3.00	0.52	3.79	25.26
CD 0.05	5.30	54.17	NS	0.14	1.37	9.97

The character wise descriptions are represented below:

4.2.1 Germination percentage (%)

The overall mean for germination percentage was 63.64 per cent with a minimum and maximum value of 48.60 per cent in genotype RZ-345 and 81.98 per cent in genotype RZ-209, respectively. The character showed genotypic and phenotypic coefficient of variability of 15.41 per cent and 19.10 per cent, respectively. Heritability estimate was 65.09 per cent which was accompanied by genetic advance of 16.30 per cent and genetic gain of 25.61 per cent.

4.2.2 Survival percentage (%)

Survival percentage varied between 5.67 per cent (RZ-345) and 12.33 per cent (GC-4) with a mean value of 8.63 per cent. The coefficient of variability was of the order of 25.50 per cent and 32.12 per cent at genotypic and phenotypic levels, respectively. Heritability estimate was of the order of 63.04 per cent with genetic advance of 3.60 per cent and genetic gain of 41.71 per cent.

4.2.3 Plant height (cm)

The mean plant height was 28.53 cm with the range of 25.59 cm (RZ-345) to 30.13 cm (GC-4). For plant height, coefficients of variability at genotypic and phenotypic levels were recorded to be 4.06 per cent and 8.89 per cent, respectively. Heritability estimate was 20.81 per cent with genetic advance of 1.09 per cent and genetic gain of 3.81 per cent.

4.2.4 Number of branches per plant

The overall average of the trait was 2.93 with the range of 2.23 (RZ-345) to 3.47 (GC-4). The character showed the genotypic coefficient of variability of 12.62 per cent and phenotypic coefficient of variability of 19.51 per cent. Heritability of 41.84 per cent with genetic advance of 0.49 per cent and genetic gain of 16.81 per cent was recorded for this character.

4.2.5 Number of umbels per plant

The mean of number of umbels per plant was 8.11 with the range of 6.61 (RZ-345) -10.91 (GC-4). Coefficients of variability at genotypic and phenotypic

levels were recorded to be 15.56 per cent and 22.55 per cent, respectively. Heritability of 47.66 per cent with genetic advance of 1.80 per cent and genetic gain of 22.13 per cent was recorded.

4.2.6 1000 seed weight (g)

The range observed for 1000 seed weight was 2.82g (RZ-345) – 3.12g (GC-4) with the average of 2.98g. The genotypic and phenotypic coefficient of variability was recorded to be 1.23 per cent and 4.29 per cent, respectively. The heritability was estimated to be 8.16 per cent with genetic advance of 0.02 per cent and genetic gain of 0.72 per cent.

4.2.7 Number of seeds per umbel

The average number of seeds per umbel was 19.85 and it showed variability between 11.20 (RZ-345) – 28.79 (GC-4). The coefficient of variability was recorded to be 29.55 and 33.25 per cent at genotypic and phenotypic levels, respectively. The heritability estimate was 78.98 per cent along with genetic advance and genetic gain of 10.74 per cent and 54.10 per cent, respectively.

4.2.8 Number of seeds per plant

The overall average of the number of seeds per plant was 168.61 with the observed range of 74.95 (RZ-345) – 313.25 (GC-4). The genotypic and phenotypic coefficients of variability were of the order of 46.58 per cent and 50.08 per cent, respectively. The heritability was estimated to be 86.52 per cent with genetic advance and genetic gain of 150.49 and 89.25 per cent, respectively.

4.2.9 Seed yield per plant

Seed yield per plant varied between 0.21g (RZ-345) – 0.98g (GC-4) with a mean value of 0.51g. For this character, coefficients of variability at genotypic and phenotypic levels were 49.60 per cent and 52.25 per cent, respectively. The heritability was estimated to be 90.14 per cent with genetic advance of 0.49 per cent and genetic gain of 97.02 per cent.

4.2.10 Seed yield per plot

Seed yield per plot varied between 1.11g (RZ-345) – 11.6g (GC-4) with a mean of 4.77g. The coefficient of variability was recorded to be 75.69 per cent and

Table 5: Estimates of variability and genetic parameters for different characters

Characters	Range	Mean	Coefficient of variability (%)		Heritability (%)	Genetic Advance (%)	Genetic gain (%)
			Genotypic	Phenotypic			
Germination percentage (%)	48.60 -74.37	63.64	15.41	19.10	65.09	16.30	25.61
Survival percentage (%)	5.67 – 12.33	8.63	25.50	32.12	63.04	3.60	41.71
Plant height (cm)	25.59 – 30.13	28.53	4.06	8.89	20.81	1.09	3.81
Number of branches per plant	2.23 – 3.47	2.93	12.62	19.51	41.84	0.49	16.81
Number of umbels per plant	6.61 – 10.91	8.11	15.56	22.55	47.66	1.80	22.13
Number of seeds per umbel	11.20 – 28.79	19.85	29.55	33.25	78.98	10.74	54.10
Number of seeds per plant	74.95 – 313.25	168.61	46.58	50.08	86.52	150.49	89.25
1000 seed weight (g)	2.82 – 3.12	2.98	1.23	4.29	8.16	0.02	0.72
Seed yield per plant (g)	0.21 – 0.98	0.51	49.60	52.25	90.14	0.49	97.02
Seed yield per plot (g)	1.11 – 11.61	4.77	75.69	77.47	95.46	7.27	152.35

77.47 per cent for genotypic and phenotypic levels, respectively. The heritability was estimated to be 95.46 per cent with genetic advance and genetic gain of 7.27 per cent and 152.35 per cent, respectively.

4.3 Correlation studies

The essence of interrelation between different characters has been carried out by calculating correlation coefficients which are presented in the Table 6. The main objective of each breeding programme for all crops is to achieve higher yield which is influenced by many traits in both positive and negative directions.

In the present study, correlation coefficients for different traits were significant for all the characters indicating interrelation between various characters except trait pairs plant height vs. number of umbels per plant, plant height vs. 1000 seed weight and number of umbels per plant vs. 1000 seed weight. The exploration of the data presented in Table 6 revealed that seed yield per plant was positively and significantly correlated with all the parameters.

Highly significant positive correlation has been observed for trait pairs seed yield per plant vs. number of seeds per plant (0.923), seed yield per plot vs. seed yield per plant (0.920), seed yield per plot vs. number of seeds per plant (0.911), seed yield per plot vs. number of seeds per umbel (0.878), number of seeds per plant vs. number of umbels per plant (0.851), seed yield per plant vs. number of seeds per umbel (0.842), number of seeds per plant vs. number of seeds per umbel (0.831), seed yield per plot vs. survival percentage (0.826), seed yield per plant vs. survival percentage (0.825), seed yield per plot vs. number of umbels per plant (0.815), number of seeds per plant vs. survival percentage (0.809), seed yield per plant vs. number of umbels per plant (0.787), survival percentage vs. germination percentage (0.776), number of seeds per umbel vs. survival percentage (0.758), seed yield per plant vs. germination percentage (0.750), number of seeds per plant vs. germination percentage (0.749), seed yield per plot vs. germination percentage (0.746), number of seeds per plant vs. number of branches per plant (0.716) and seed yield per plant vs. number of branches per plant (0.710).

Moderately significant correlation has been observed for trait pairs viz. number of seeds per umbel vs. number of umbels per plant (0.692), number of seeds

per umbel vs. germination percentage (0.679), number of seeds per umbel vs. number of branches per plant (0.670), number of seeds per umbel vs. plant height (0.645), seed yield per plot vs. number of branches per plant (0.625), number of umbels per plant vs. survival percentage (0.578), plant height vs. survival percentage (0.570), number of umbels per plant vs. number of branches per plant (0.561), seed yield per plot vs. plant height (0.535), number of branches per plant vs. survival percentage (0.530), number of branches per plant vs. germination percentage (0.529), seed yield per plot vs. 1000 seed weight (0.514), number of seeds per plant vs. plant height (0.510), number of umbels per plant vs. germination percentage (0.481), seed yield per plant vs. 1000 seed weight (0.473), number of seeds per umbel vs. 1000 seed weight (0.473), 1000 seed weight vs. number of branches per plant (0.455), number of seeds per plant vs. 1000 seed weight (0.451), 1000 seed weight vs. survival percentage (0.438), plant height vs. germination percentage (0.422) and 1000 seed weight vs. germination percentage (0.406).

Non significant positive correlation was observed for trait pairs viz. number of umbels per plant vs. plant height (0.342), 1000 seed weight vs. number of umbels per plant (0.328) and 1000 seed weight vs. plant height (0.255).

Table 6: Correlation between different growth and yield parameters

Characters	Germination percentage (%)	Survival percentage (%)	Plant height (cm)	Number of branches per plant	Number of umbels per plant	1000 seed weight (g)	Number of seeds per umbel	Number of seeds per plant	Seed yield per plant (g)	Seed yield per plot (g)
Germination percentage	1									
Survival percentage	0.776**	1								
Plant height	0.422*	0.570*	1							
Number of branches per plant	0.529*	0.530*	0.487*	1						
Number of umbels per plant	0.481*	0.578*	0.342	0.561*	1					
1000 seed weight	0.406*	0.438*	0.255	0.455*	0.328	1				
Number of seeds per umbel	0.679**	0.758**	0.645**	0.670**	0.692**	0.473*	1			
Number of seeds per plant	0.749**	0.809**	0.510*	0.716**	0.851**	0.451*	0.831**	1		
Seed yield per plant	0.750**	0.825**	0.537*	0.710**	0.787**	0.473*	0.842**	0.923**	1	
Seed yield per plot	0.746**	0.826**	0.535*	0.625**	0.815**	0.514*	0.878**	0.911**	0.920**	1

*Significant at 5% level

** Significant at 1% level

Discussion

DISCUSSION

India is known as “The Home of the spices” and seed spices occupy an important place in agricultural production system and national economy. In the recent years, spices have provided a wide alternative to the farmers being cash crop. The demand for spices has increased globally due to their various uses. Seed spices are one of the key spice commodity produced pre-dominantly on Indian soils due to congenial weather conditions prevailing in the semi arid and arid tropics of Indian sub-continent. The biodiversity of spices and its conservation needs specific priority because of their diverse use and the potential to provide livelihood security.

In the present investigation, an effort has been initiated to introduce cumin in the subtropical belt of Jammu to give wider choice for diversification to farmers keeping in view the changing climate. Besides introduction, higher yield is also important to make the species commercially viable. Therefore, different genotypes of *Cuminum cyminum* were evaluated for their growth and yield parameters so as to get information on variability present in them and to know the degree of association between different yield contributing characters and thereby identification of the superior genotype(s) for subtropics of Jammu region. The results obtained during the present investigation on **“Evaluation of germplasm of cumin (*Cuminum cyminum* Linn.) under subtropics of Jammu”** have been discussed in this chapter with suitable and reasonable explanation in the light of available literature under following heads:

5.1 Evaluation of different genotypes of cumin for growth and yield parameters

One of the most important approaches to increase yield of any species lies with developing suitable strain by selecting genetically superior lines among existing populations. Cultivation of superior genotypes will help in increasing the production of species making it commercially viable. *Cuminum cyminum* is one such species used in Indian culinary and is mainly grown in Rajasthan and Gujarat besides Madhya Pradesh, Uttar Pradesh, Punjab and Maharashtra. In this context, eight genotypes of *Cuminum cyminum* procured from SKNAU, Jobner, Rajasthan formed the basic genetic material which has been assessed for eleven characters. Almost all the

characters studied recorded statistically significant variations except for plant height and 1000 seed weight which is the clear cut indication of existence of high amount of variability among these genotypes. An appraisal of the data in Tables 3 and 4 revealed that overall performance of the crop was not good but genotype GC-4 and RZ-209 performed better than other genotypes. GC-4 ranked first for possessing maximum value for survival percentage (%), number of branches per plant, number of umbels per plant, number of seeds per umbel, number of seeds per plant, 1000 seed weight (g), seed yield per plant (g), seed yield per plot (g) and estimated seed yield (kg/ha). For germination percentage and plant height this genotype ranked second. Genotype RZ-209 ranked second for characters like number of branches per plant, number of umbels per plant, number of seeds per umbel, number of seeds per plant, 1000 seed weight (g), seed yield per plant (g), survival percentage (%), seed yield per plot (g) and estimated seed yield (kg/ha) while as it ranked first for germination percentage and third for plant height. On the basis of the performance and taking all the characters into consideration on overall basis, it could be brought out that genotypes GC-4 and RZ-209 were superior over others. These genotypes appear genetically distinct from the others as far as the characters of the plant contributing to the economic yield are concerned.

5.1.1 Mean performance of growth and yield parameters of different genotypes

The main aim of evaluation of different genotypes is to determine inherent differences among different varieties and manipulate them in desired direction to obtain good results. The observed value of a trait measured on an individual is the phenotypic value of that individual. This value is partly due to the genes which the individual receives from its parents and partly due to the environment in which it is raised. The particular assemblage of the genes possessed by the individual is its genotype along with the sum total cumulative effects of genes is called its genotypic value.

Elucidation of Tables 3 and 4 revealed significant variation among eight genotypes of *Cuminum cyminum* on the basis of mean performance of all characters. The mean performance helps to identify superior genotype among existing populations. It also serves as a primary criteria for selection of desirable plants (Kumar *et al.*, 1979).

Among the eight genotypes evaluated, RZ-209 recorded the highest significant value (81.98%) for germination percentage which was followed by GC-4 (74.37%) and RZ-223 (67.05%). Lowest germination percentage was recorded in RZ-345 (48.60%). Neamatollahi *et al.* (2009) have also reported a similar range of seed germination percentage (20-84%) from hydropriming and osmopriming effects on Cumin (*Cuminum Cyminum* L.). Dayal *et al.* (2001) have also reported germination values of 13.33 per cent to 100 per cent in cumin under salinity and normal conditions in Rajasthan. Heidari and Sadeghi, (2014) have also suggested that 400ppm of GA₃ in combination with 25°C temperature results in better seed germination and seedling growth characters in cumin seeds. The values for survival percentage ranged between 5.67 per cent-12.33 per cent which is extremely low, highest being in genotype GC-4. But the overall values for survival percentage were very low which may be due to the frequent rains and low temperature (Fig. 1) during the cropping season resulting in the continuous water retention in field and ultimately the mortality of the crop. However, the cumin crop requires dry weather during growth period (Kumar, 2018). The findings are in contradiction to the reports of earlier workers (Bairwa *et al.*, 2015; Meena *et al.*, 2015 and Kahrizi *et al.*, 2011) from Rajasthan, Gujarat and Iran where crop perform well.

Among the surviving population, the higher value of plant height was recorded in genotype RZ-223 (30.31cm) followed by GC-4 (30.13cm) and RZ-209 (29.99cm). The lowest plant height was recorded in genotype RZ-345 (25.59cm). These results are in line with the findings of Meena *et al.* (2015) and Jat and Singh (2016) who have also reported the similar observations in plant height after evaluation of cumin germplasm in Jobner, Rajasthan. Maximum number of branches per plant was observed in genotype GC-4 (3.47), while minimum number of branches per plant was recorded in genotype RZ-345 (2.23). These results are in conformity with the reports of Meena *et al.* (2016) who have recorded similar range (2.00-8.00) for number of branches while evaluating different genotypes. However, the branches recorded in the present investigation are less than as reported by Jat and Singh (2016), wherein 3.77–4.83 branches per plant have been reported. Highest significant value for number of umbels per plant was recorded in genotype GC-4 (10.91) followed by genotype RZ-209 (9.62). Lowest number of umbels per plant was recorded in genotype RZ-345 (6.61). These results are in contradiction with the findings of Jat

and Singh (2016), Bairwa *et al.* (2015) and Meena *et al.* (2015) who have reported higher number of umbels per plant (even up to 37.00). Maximum number of seeds per umbel was recorded in genotype GC-4 (28.79) followed by RZ-209 (25.14). Lowest number of seeds per umbels (11.20) was recorded in RZ-345 (Fig. 11).

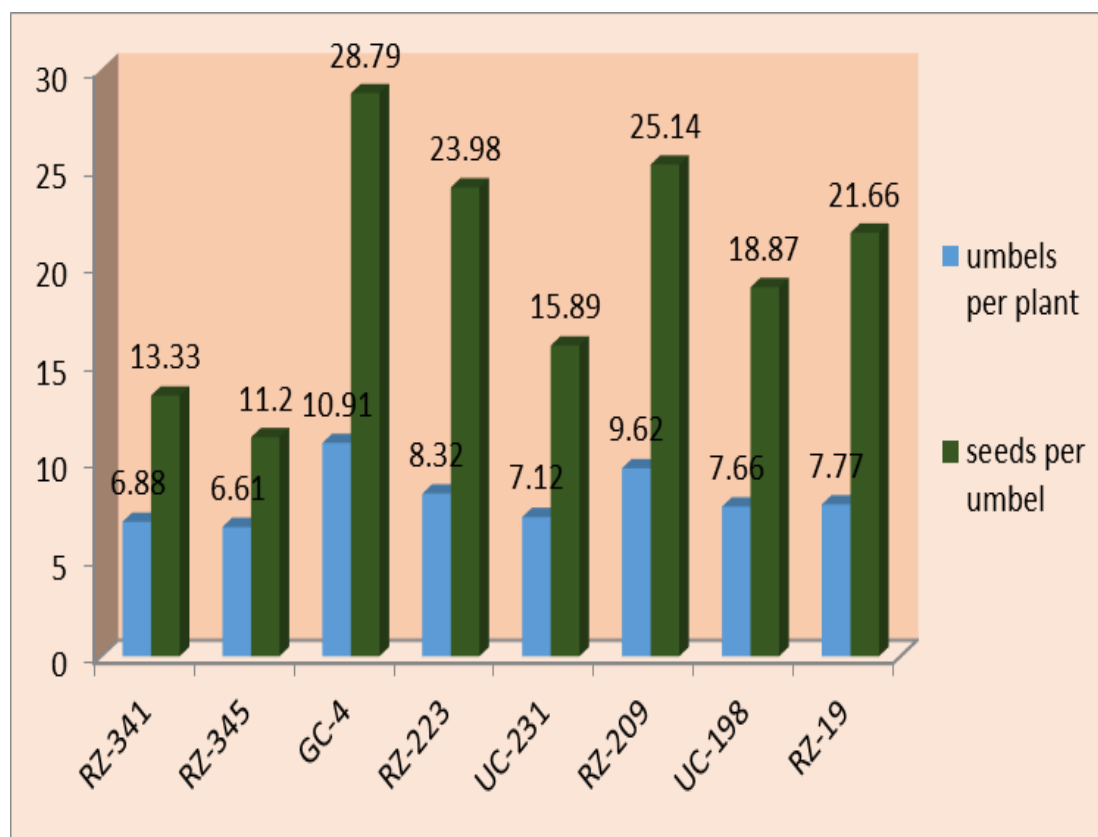


Fig. 11 Umbels per plant and seeds per umbel in different genotypes

Maximum number of seeds per plant was recorded in GC-4 (313.25) and lowest number of seeds per plant was recorded in RZ-345 (74.95). The number of seeds obtained are at the lower range as compared to results obtained by other workers (Ahmadian, *et al.*, 2011 and Motamedi-Mirhosseini, *et al.*, 2011) which may be due to the severe rains during the growing period resulted in the decrease in the number of umbels and ultimately reduction in the number of seeds per plant (Fig.12). Maximum 1000 seed weight was observed in genotype GC-4 (3.12g), while as minimum 1000 seed weight was recorded in genotype RZ-345 (2.82g). Bairwa *et al.* (2015) also found the same range (1.25- 4.68) for 1000 seed weight in cumin. Maximum seed yield per plant was recorded for genotype GC-4 (0.98g) which was followed by RZ-209 (0.73g) and RZ-223 (0.60g). Lowest seed yield per plant was recorded in genotype RZ-345 (0.21g). These results are in contradiction with the

findings of Meena *et al.* (2015), Jat and Singh (2016), Bairwa *et al.* (2015) who have reported seed yield per plant of 35.72g, 13.09g and 1.95g, respectively in cumin. These results are also in contradiction with the report of National Research Centre on Seed Spices, Ajmer where the maximum seed yield per plant of 131.17g was recorded in entry AC-WMT-16-40 (NRCSS, 2014).

The estimated seed yield per hectare in the present study was in the range of 7.42-77.42 kg ha⁻¹ (Fig. 16), highest being in genotype GC-4 and lowest in genotype RZ-345. The potential of these genotypes/varieties ranges from 560-1250 kg ha⁻¹ in Rajasthan and Gujarat as reported by Kumar (2018). All the growth and yield parameters of the cumin recorded in the present study falls on the lower side of the range as compared to earlier reports of Bairwa *et al.* 2015; Jat and Singh, 2016 and Meena *et al.* 2015. This might be due to higher rainfall, low temperature and frost occurrence in this region (Fig. 1) There was continuous rains from the month of January to April 2019 i.e. the growth period of the crop which resulted in the stagnation of the water in the beds resulting in mortality of the crop/low survival percentage. The highest rainfall of 67.8mm was received in the second fortnight of February, 2019 which resulted in less flowering and thereby reduction in the seed yield per plant and ultimately decrease in seed yield per hectare.

The ultimate objective of this study is to obtain higher yield in terms of branches, umbels and seeds. The number of branches per plant, number of umbels per plant, number of seeds per umbel and number of seeds per plant are extremely important yield attributes in cumin under field condition. The highest number of branches per plant (3.47), umbels per plant (10.91), seeds per umbel (28.79), seeds per plant (313.25) and seed yield per plant (0.98g) was recorded in the genotype GC-4.

5.1.2 Estimates of variability and genetic paramaters

Variability within the population is a natural phenomenon and the magnitude of variability present in a species is of utmost importance, as it provides basis for effective selection. The effectiveness of selection of plants from a large population for desired traits within the mixed population will depend on how much the variation in characters is due to environment in which plants are growing and the extent to which the variability present in population as a result of genetic factors. The total variation

in a population arises due to genotypic and environmental effects. For plant breeders it is the genotypic variation which is of main concern. There are better chances of producing the desirable types when the range of variability in the initial material is greater. For plant improvement, knowledge of heritability for different traits is essential because it is inherited from generation to generation. Heritability components comprise of additive and non-additive and it is the former which respond to selection (Wright 1921). Genetic coefficient of variation together with heritability estimate would give reliable indication of extent of improvement through selection and expected genetic gain provides practical information which is needed by a breeder. Therefore, the knowledge of parameters of variability viz. phenotypic coefficient of variation, genotypic coefficient of variation and environmental coefficient of variation, genetic advance and heritability is useful for development of superior genotypes with high yield potential.

In the present study, the results obtained for different characters with regards to variability parameters (Table 5) indicate that mean values have a wider range indicating the presence of good amount of variability. However, the range is narrow for 1000 seed weight which indicates slow improvement in selection, if this character was taken into consideration. Narrow range in this parameter have also been reported earlier by Ramavtar. Higher values of genotypic coefficient of variation and phenotypic coefficient of variation was obtained for seed yield per plot, seed yield per plant and number of seeds per plant which indicates the substantial variability existing for these characters with greater scope of selection for better expression. Singh *et al.* (2001) have also reported high genotypic and phenotypic coefficient of variation for grain yield, umbels per plant, grains per umbel and harvest index. On the other hand, 1000 seed weight, plant height, number of branches per plant, germination percentage, number of umbels per plant and survival percentage showed low GCV and PCV. This indicates the influence of environmental factors in the expression of characters and therefore, cannot be considered reliable for selection. Characters with both high and low GCV and PCV have earlier been reported by Bairwa *et al.* (2015) and Meena *et al.* (2016) in cumin.

Heritability and genetic advance provide information about the extent to which a character is heritable and level of improvement which can be achieved through selection. In the present investigation, higher heritability was observed for

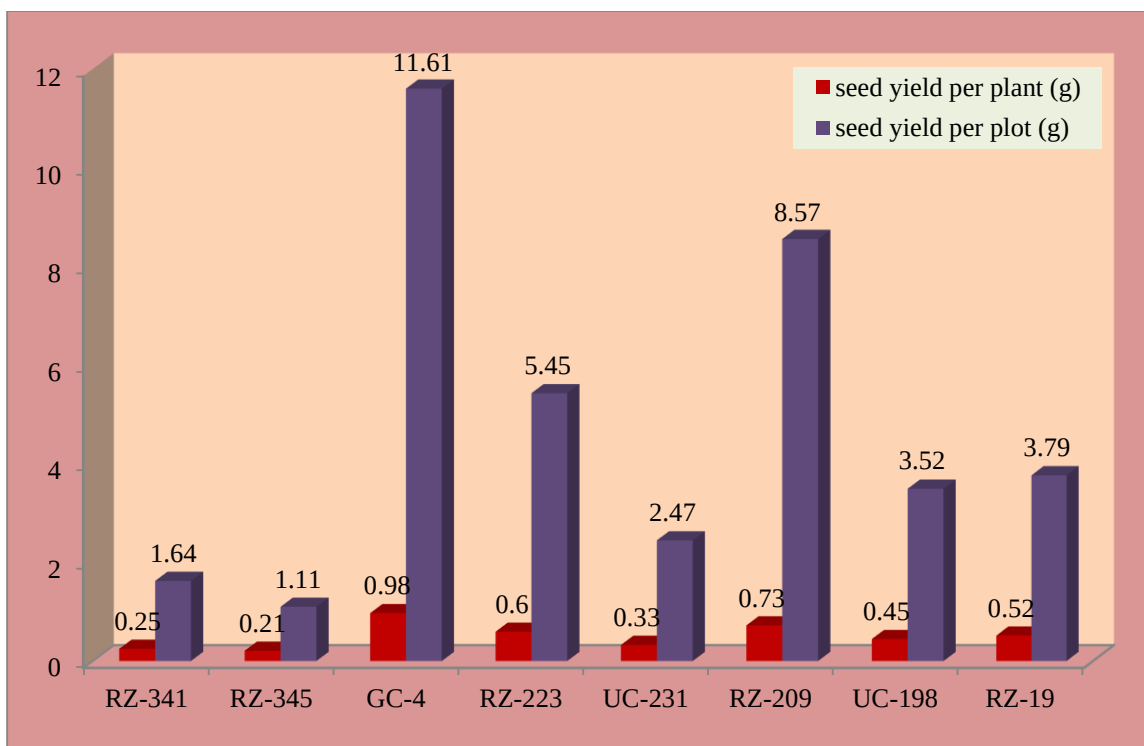


Fig.12 Seed yield performance of different genotypes

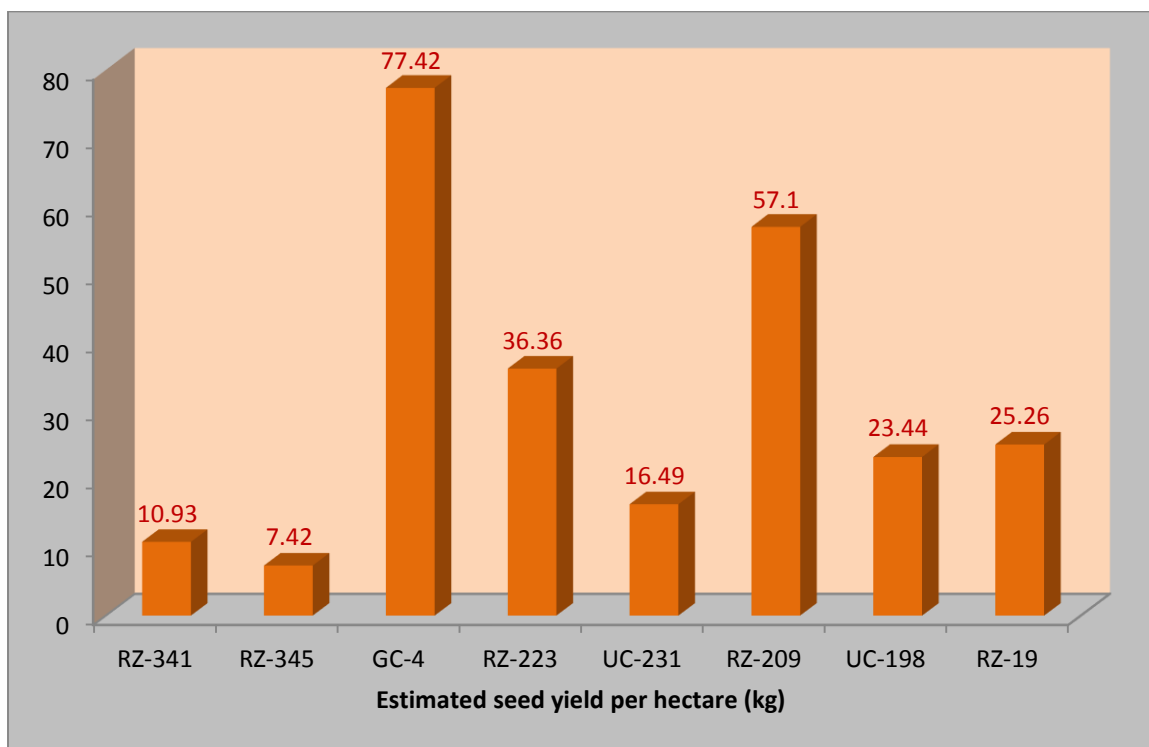


Fig. 13 Estimated seed yield in different genotypes

seed yield per plot. Seed yield per plant, number of seeds per plant and number of seeds per umbel. Higher heritability observed for these characters might be due to additive effects and selection pressure could be profitably applied on these characters for yield improvement. Johnson *et al.* (1955) observed that heritability estimates along with genetic gain is more useful information than the heritability alone in predicting the resultant effect for selecting the best individuals. 1000 seed weight, plant height and number of branches per plant revealed low genetic gain. These characters seem to be controlled by non-additive gene action. On the other hand, seed yield per plot, seed yield per plant, number of seeds per plant and number of seeds per umbel indicate high genetic gain and thus can safely be considered for obtaining more of genetic improvement in a population through selection. Singh *et al.* (2001) have also reported high genetic gain and genetic advance for plant height, biological yield and seed yield in normal conditions in Rajasthan. These results are also in agreement with the findings of Meena *et al.* (2016) in cumin.

5.1.3 Correlation studies

The most important and complex character is yield which is influenced by many physiological processes within the plant. It is also influenced by the environmental factors in which plant is grown. Therefore, it may create confusion and give a biased performance if selection is done based on yield performance only; consequently a rational approach towards the improvement of yield necessitates the selection of desirable components of yield. The biometrical tool “correlation” indicates the intensity and direction of association of a character with yield. The interrelationship of characters of growth and yield attributing characters provides the information about the likely consequences of selection for simultaneous improvement of desirable characters under consideration. Based on the estimation of phenotypic and genotypic correlation, the breeder decides the breeding methodology to be followed so that the useful correlation can be exploited and undesirable ones can be modified by generating fresh variability to obtain new recombinants.

In the present investigation, the correlation coefficients were worked out for all the 11 characters (Table 6) and all the combinations were positively and significantly correlated with each other except for trait pairs number of umbels per plant vs. plant height, 1000 seed weight vs. plant height and 1000 seed weight vs.

number of umbels per plant which were positively correlated but non-significant. Jat and Singh (2016) have also reported positive significant correlation of seed yield with seeds per plant, biological yield and branches per plant.

In the present investigation, germination percentage, survival percentage, number of branches per plant, number of umbels per plant, number of seeds per umbel, number of seeds per plant, seed yield per plant and seed yield per plot showed high positive association with seed yield per plant, thus suggesting that these characters are important yield components and the effective improvement in yield can be achieved through selection based on these characters. On the other hand, plant height and 1000 seed weight exhibited a nonsignificant but positive correlation with the seed yield per plant. Relentlessly, majority of these characters have also high heritability coupled with moderately high genetic gain, thus indicating additive genetic nature of the heritable component present in them. Therefore, selection for these attributes would bring about desirable improvement in the species under study for seed yield. Meena *et al.* (2015) have also observed positive correlation between seed yield and number of umbels per plant. These results are in agreement with the findings of Bairwa *et al.*, 2015; Jat and Singh, 2016 and Meena *et al.*, 2016 who have reported positive correlation of seed yield with above mentioned characters in cumin under arid conditions of Rajasthan. Kahrizi *et al.* (2011) also reported positive correlation between yield and number of seeds per plant, number of umbels per plant, number of seeds per umbel, 1000 seed weight and biological yield in Iran.

Summary and Conclusions

SUMMARY AND CONCLUSIONS

The present study entitled “**Evaluation of germplasm of cumin (*Cuminum cyminum* Linn.) under subtropics of Jammu**” was conducted at Experimental Farm of Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu. The basic purpose of this study was to study the performance of cumin under Jammu subtropics and to identify superior genotype(s) for the region. Identification of superior genotypes among the existing populations is key parameter to increase its yield. Keeping this in mind, the present investigation was conducted to evaluate the different genotypes for growth and yield characters. This experiment was conducted with eight genotypes under Randomized Block Design with three replications in each. The salient features of the investigation are summarized below:

Eight genotypes of cumin (*Cuminum cyminum*) obtained from SKNAU, Jobner, Rajasthan formed the base material to study the growth performance and to find out variability among them. From the analysis of variance, it is evident that the genotypes differed significantly for growth and yield parameters. Although seed germination was moderate but low survival percentage of 5.67-12.33% was recorded which ultimately lead to low seed yield per hectare. Seed yield per plant and seed yield per plot varied from 0.21- 0.98g and 1.11-11.61g, respectively among different genotypes. Among the genotypes, higher seed yield per plant was observed in genotype GC-4 (0.98g) followed by RZ-209 (0.73g) and RZ-223 (0.60g). Estimated seed yield ranged from 7.42-77.42kg ha⁻¹ highest being in genotype GC-4 and lowest in genotype RZ-345.

Analysis of variance showed significant amount of genetic variability among genotypes for all characters except plant height and 1000 seed weight. Wide range of variability was observed in the mean value of most of the growth and yield parameters viz. germination percentage (63.64%), survival percentage (8.63%), plant height (28.53), number of umbels per plant (8.11), number of seeds per umbel (19.85), number of seeds per plant (168.61) and seed yield per plot (4.77). The values for genotypic coefficient of variability and phenotypic coefficient of variability were

higher for characters viz. seed yield per plot (75.69%, 77.47%), seed yield per plant (49.60%, 52.25%) and number of seeds per plant (46.58%, 50.08%), respectively where as moderate estimates were recorded for number of seeds per umbel (29.55%, 33.25%), survival percentage (25.50%, 32.12%), number of umbels per plant (15.56%, 22.55%), number of branches per plant (12.62%, 19.51%) and germination percentage (15.41%, 19.10%), respectively. Low estimates of PCV and GCV was recorded for 1000 seed weight (1.23%, 4.29%) and plant height (4.06%, 8.89%) respectively. Higher estimates of heritability was observed for seed yield per plot (95.46%), seed yield per plant (90.14%), number of seeds per plant (86.52%), number of seeds per umbel (78.98%), germination percentage (65.09%) and survival percentage (63.04%) which indicate that these characters can be easily improved through selection. High estimates of genetic advance and genetic gain was recorded for number of seeds per plant and seed yield per plot, respectively. All the characters and combinations were positively and significantly correlated with each other except for trait pairs viz. number of umbels plant⁻¹ vs. plant height, 1000 seed weight vs. plant height and 1000 seed weight vs. number of umbels plant⁻¹ which were positively correlated but non-significant. Seed yield plant⁻¹ was significantly and positively correlated with number of seeds plant⁻¹ (0.923), number of seeds umbel⁻¹ (0.842), survival percentage (0.825), number of umbels plant⁻¹ (0.787), germination percentage (0.750) and number of branches plant⁻¹ (0.710).

CONCLUSION

- Out of eight genotypes, genotype GC-4 is superior over others resulting in higher seed yield.
- Higher heritability along with high genetic gain was observed for number of seeds per umbel, number of seeds per plant, seed yield per plant and seed yield per plot which indicate sufficient potential for improvement in the species through selection of these traits.
- Cumin is not commercially viable crop for Jammu subtropics due to poor survival, growth and yield performance.

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APPENDIX – I

Analysis of variance for different characters

Source of variation	d.f	Germination percentage (%)	Survival percentage (%)	Plant height cm	Number of branches plant ⁻¹	Number of umbels plant ⁻¹	1000 seed weight (g)	Number of seeds umbel ⁻¹	Number of seeds plant ⁻¹	Seed yield plant ⁻¹ (g)	Seed yield per plot (g)	Estimated seed yield (kg/ha)
Replication	2	0.83	0.25	0.60	1.01	0.10	0.004	3.23	6327.37	0.004	2.27	41.80
Genotypes	7	2380.41	121.62	63.84	4.21	45.70	0.13	786.77	136266.4	1.39	278.10	12358.16
Error	14	722.01	39.75	71.38	2.62	24.53	0.21	128.25	13396.78	0.09	8.61	454.500

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University	SKUAST-Kashmir
Percentage of Marks	7.88/10 (78.8%)
Master's of Degree	M.Sc. Forestry
University	SKUAST-Jammu
OGPA	7.90/10 (79%)
Title of Master's Thesis	“Evaluation of Germplasm of Cumin (<i>Cuminum cyminum</i> Linn.) under Subtropics of Jammu”

CERTIFICATE - IV

Certified that all the necessary corrections as suggested by the external examiner and the Advisory committee have been duly incorporated in the thesis entitled "Evaluation of Germplasm of Cumin (*Cuminum cyminum* Linn.) under Subtropics of Jammu" submitted by Ms. Amreena Akhter, Registration Number J-17-M-494.


Dr. L. M. Gupta
Major Advisor and Chairman
Advisory Committee

Place: Chatha, Jammu

Date: 22-11-2019


Head 22/11/2019
Division of Agroforestry