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Genetic variability, correlation and path analysis in ajwain (*Trachyspermum ammi* L.)

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Abstract
The variability is the basic requirement in any breeding programme, so, in this research an attempt was made to assess the morphological variability using seventeen characters in ajwain. Mean sum of square due to treatment was found highly significant for all the characters. In the present findings phenotypic coefficient of variations were observed to be higher than the corresponding genotypic coefficient of variation for all the characters studied. The values of heritability in broad sense were observed very high for all th seventeen characters. However, it is not necessary that a character showing high heritability will also exhibit high genetic advance. From the study of character association ships, among the correlation analysis the characters namely, harvest index (%)**,** number of umbels per plant, number of seeds per umbel, number of branches per plant at 150 DAS, number of flowers per umbellates, number of umbellates per umbel, essential oil (%), plant height at 150 DAS, oleoresin (%) and test weight (g) have positive correlation and the path analysis revealed that the traits such as number of seeds per umbel followed by number of branches at 150 DAS, test weight (g), days to germination and oleoresin (%) had direct positive effect on seed yield per plant. Hence further improvement in these characters would be achieved by phenotypic selection.

Keywords: Variability, GCV, PCV, heritability, genetic advance

1. Introduction

Trachyspermum ammi L. Syn. *Carum copticum*, commonly known as Bishop's weed or ajwain or ajwain, cultivated as herbaceous herb belonging to the family Apiaceae and vastly grows in Egypt, Iran, Pakistan, Afghanistan, and India as well as European region (Shojaaddini *et al*., 2008) [29]. Usually greyish brown seeds or fruits of ajwain are considered for medical and nutritional purposes (Chauhan *et al*., 2012) [4]. It has been used as culinary spice worldwide and resembles thyme. Fruits were widely administered as a food flavouring agent and as a digestive stimulant (Jeet *et al*., 2012) [11]. Ajwain fruits are used as a medicament in Unani, Ayurvedic and Arab traditional medicine for its diuretic, analgesic, antiasthmatic, anthelmintic and antispasmodic properties (Zahin *et al*., 2010) [40]. According to Pathak *et al.* (2010) [21] the thymol and carvacrol derivatives and other minor components of ajwain are responsible for its functional properties.

Rajasthan, Gujarat, Madhya Pradesh, Uttar Pradesh, Maharashtra, West Bengal, Bihar, Telangana and Andhra Pradesh are among the Indian states, where ajwain is grown (Mohsenzadeh *et al*., 2012) [41]. In an area of 41,134 hectare, 28,973 tonnes of ajwain seeds were produced in 2019-2020. Ajwain has a current average productivity of 704 kg/ha. Andhra pradesh is leading with respect to area (10.992 ha), whereas Gujarat is leading with respect to production (10.599 t) and Madhya Pradesh is leading with respect to productivity (1108 kg/ha) (Spice Board, 2020) [36]. Ajwain farming has extended in Bidar, Gulburga, Raichur, Vijayapura and Bagalkote districts of Karnataka in recent years (Anon., 2018) [1].

Any successful breeding effort for a crop species requires genetic variability, hence it is crucial to assess genetic variability before beginning an improvement programme to create high yielding varieties (Falconer, 1981) [8]. Genetic variability available in the germplasm collection of a species is a basic requirement for its crop improvement programme. Genetic analysis of ajwain is essential to enhance the yield potential and maximum utilization of the desirable characters for development of any ideal genotypes (Nagar *et al.* 2019) [42]. The survey of genetic variability with the help of suitable genetic parameters like genotypic and phenotypic coefficients of variations, heritability estimates and genetic advance as percentage of mean are indispensable in breeding programmes aimed at improvement of seed yield.

(Dhakad *et al.* 2017) [7]. A measurement of the sort of gene activity involved in the manifestation of different phenotypes is the size of these components. Information on gene activity aids in selecting a breeding strategy for the genetic improvement of characteristics (Singh and Narayanan, 2007) [33]. However, by leveraging existing diversity, high-yielding open pollinated varieties may be created (Islam *et al*., 2009) [10] and this method might be applied to enhance ajwain.

For a breeding programme to be successful, selecting acceptable genotypes from a germplasm is aided by knowledge of the nature and degree of genetic diversity. The value of a germplasm collection is influenced by the genetic diversity contained in those accessions as well as the quantity of accessions. Only the genetic variability is heritable, and the observable variability is a composite estimate of genetic and environmental factors. To get a sense of the predicted gain in the following generation, the estimate of heritability must be taken into account with genetic progress (Vishwas *et al.* 2020) [37].

Seed yield being a complex polygenic trait composed of several components some of which affect yield directly while; others were contributing towards it indirectly. The knowledge of the magnitude and direction of interrelationship between yield and its component characters has great importance in breeding programmes for the selection of desirable types, when correlation studies involve, many characters then it becomes difficult to determine the importance of each of the factors (Dhakad *et al.* 2017) [7]. Therefore, an attempt was made in the present investigation to estimate analysis of variance, magnitude of genetic variability, heritability, genetic advance, correlation and path analysis in twenty eight ajwain genotypes, which can be utilized as future breeding programme.

2. Material and methods

2.1 Experimental site and location

The present investigation on "Genetic variability in ajwain genotypes" was conducted at the Department of Plantation, Spices, Medicinal and Aromatic Crops at University of Horticultural Sciences, Bagalkot. Twenty-eight germplasm were evaluated during 2020-21 and 2021-22 of *rabi* season for growth yield and quality traits. Out of 28 genotypes, 16 were released varieties and 12 were local collections. The experiment was laid out in a randomized complete block design and replicated twice. The experimental field was ploughed twice to get fine tilth and prepared flat beds size of 2.5 X 2.1m^2, spacing - 45 x 30 cm. Recommended dose of fertilizer (100: 50: 50 NPK kg ha^{-1}) was applied in the form of urea at 217.00 kg per ha, MOP at 83.00 kg per ha and SSP at the rate of 312.50 kg per ha. Full dose of potash, phosphorous and half dose of nitrogen were applied as basal dose and remaining nitrogen was given after 30 days after sowing (DAS). In each replication and in each treatment five plants were randomly selected and tagged for observation.

2.2 Analysis of variances

The data recorded for all the characters were subjected to analysis of variance with the formula suggested by Panse and Sukhatme (1978) [19].

2.3 Estimates of genetic variability

Genotypic, phenotypic and environmental variances were computed based on the expected mean sum of squares from the ANOVA. Phenotypic and genotypic coefficient of variances was estimated according to Burton and Devane (1953) [2] based on estimate of genotypic and phenotypic variance. Burton and Devane (1953) [2] classified GCV and PCV as follows, Low: Less than 10%; Moderate: 10-20%; High: More than 20%. Heritability in broad sense was estimated as the ratio of genotypic variance to the phenotypic variance and expressed in percentage (Falconer, 1981) [8]. Robinson *et al.* (1949) [25] classified heritability percentage as follows, Low: Less than 30%; Moderate: 30-60%; High: More than 60%. Genetic advance over mean was calculated according to Johnson *et al.* (1955) [12]. Classified genetic advance as percentage over mean as follows, Low: Less than 10%; Moderate: 11-20%; High: More than 20%.

2.4 Correlation analysis

To examine the degree of association of traits with growth, yield and also among the yield components between the genotypes, the correlation coefficient were estimated and tested as per procedures narrated by Panse and Sukhatme (1967) [19].

2.5 Path coefficient analysis

Path co-efficient analysis suggested by Wright (1921) [38] and Dewey and Lu (1959) [6] was worked out to know the direct and indirect outcome of the morphological traits on plant yield.

3. Results

3.1 Analysis of variance

Mean sum of squares due to replication, genotypes and error of the experiment was calculated for the pooled data were presented in table 1. The analysis of variance showed highly significant differences among the genotypes for all the parameters such as number of flowers per umbellates, days to flower initiation (10%), number of umbellates per umbel, number of umbels per plant, number of seeds per umbel, harvest index (%), seed yield per plant (g), essential oil (%), oleoresin (%), days to germination, plant height at 150 DAS, number of branches per plant at 150 DAS and days to 50 percent flowering.

3.2 Estimates of genetic variability parameters in ajwain genotypes

3.2.1 Genotypic (GCV) and Phenotypic (PCV) coefficient of variation

Estimates of high variability of twenty-eight genotypes in respects of seventeen characters have been presented in table 2.

High PCV and GCV was showed for number of umbels per plant (44.61%, 44.46), number of seeds per umbel (38.11%, 36.70), seed yield per plant (g) (26.97%, 26.46%), seed yield per plot (g) (33.37%, 31.98%) and (33.69%, 32.13%) (kg/ha), harvest index (%) (27.64%, 25.38%), essential oil (%) (26.87%, 26.67%), oleoresin (%) (33.84%, 33.83%), the estimates of PCV and GCV were close to each other. Moderate GCV and PCV was observed for days to germination (11.60%, 10.40%), test weight (g) (14.29%, 14.27%), number of branches per plant at 150 DAS (11.95%, 10.94%) and number of flowers per umbellates (19.79%, 19.33%). Low GCV and PCV was observed for plant height at 150 DAS (8.60%, 6.94%), days to flower initiation (10%) (9.15%, 8.44%), days to 50 percent flowering (7.71%, 6.85%), number of umbellates per umbel (10.65%, 9.50%) and days to physiological maturity (5.04%, 4.45%).

3.2.2 Estimation of heritability and genetic advance

The heritability estimates in broad sense were high for most of the characters (Table 2), it indicating that though the character is least influenced by the environment effects.

High heritability was noticed for days to germination (80.30%), number of branches per plant at 150 DAS (83.80%), days to flower initiation (10%) (85.10%), days to 50 percent flowering (78.90%), number of flowers per umbellates (95.40%), number of umbels per plan (99.30%), number of seeds per umbel (92.70%), seed yield per plant (g) (96.30%), plant height at 150 DAS (65.10%), days to physiological maturity (78.00%), number of umbellates per umbel (79.60%), seed yield per plot (g) (91.80%) and (91.00%) (kg/ha), harvest index (%) (84.40%), test weight (g) (99.70%), essential oil (%) (98.50%) and oleoresin (%) (99.90%). High genetic advance was noticed for number of branches per plant at 150 DAS (20.63%), number of flowers per umbellates (38.90%), number of umbels per plant (91.28%), number of seeds per umbel (72.80%), seed yield per plant (g) (53.48%), seed yield per plot (g) (54.55%) and (63.14%) (kg/ha), harvest index (%) (48.02%), test weight (g) (29.34%), essential oil (%) (54.52%) and oleoresin (%) (69.65%). Moderate genetic advance over mean noticed for days to germination (19.20%), plant height at 150 DAS (11.54%), days to flower initiation (10%) (16.04%), days to 50 percent flowering (12.53%) and number of umbellates per umbel (17.46%). Low genetic advance over mean was noticed for days to physiological maturity (8.10%).

3.3 Correlation

The genotypic and phenotypic association between dependent and independent traits in ajwain was estimated for pooled data and represented in table 3 and 4.

At genotypic level, total seed yield of plant (g) was positively and highly significantly associated with harvest index (%) (0.971), number of umbels per plant (0.965), number of seeds per umbel (0.950), number of flowers per umbellates (0.912), number of branches per plant at 150 DAS (0.892), number of umbellates per umbel (0.844), plant height at 150 DAS (0.842), essential oil (%) (0.650), test weight (g) (0.461) and oleoresin (%) (0.325). It was negatively and significantly associated with days to 50 percent flowering (-0.907), days to flower initiation (10%) (-0.881) and days to germination (-0.809).

At phenotypic level, total seed yield of plant (g) was positively and highly significantly associated with harvest index (%) (0.925), number of umbels per plant (0.922), number of seeds in an umbel (0.910), number of flowers per umbellates (0.879), number of umbellates per umbel (0.774), number of branches per plant at 150 DAS (0.755), essential oil (%) (0.618), plant height at 150 DAS (0.581), test weight (g) (0.441) and oleoresin (%) (0.314). It was negatively and significantly associated with days to flower initiation (10%) (-0.724), days to 50 percent flowering (-0.685) and days to germination (-0.629).

3.4 Path analysis

Genotypic path coefficients for yield per plant with 13 independent characters are presented in table 5.

For total seed yield per plant high positive direct effect was expressed by number of seeds per umbel (3.040) followed by number of branches at 150 DAS (2.033), test weight (g) (0.566), days to germination (0.531) and oleoresin (%) (0.056), whereas number of flowers per umbellates (-1.416), harvest index (%) (-1.035), number of umbellates per umbel (-0.976), days to 50 percent flowering (-0.841), plant height at 150 DAS (-0.582), number of umbels per plant (-0.543), essential oil (%) (-0.442) and days to flower initiation (10%) (-0.171) had negative direct effect on total yield per plant.

4. Discussion

4.1 Analysis of variance

Mean sum of square due to treatment was found highly significant for all the characters, indicated the presence of high magnitude of variability present among the genotypes (Singh *et al*., 2019) [43]. The variation among the genotypes was a result of genotype and environment interaction. This specifies the magnitude of variability exhibited among the genotypes for the characters studied and also indicates that extensive scope for improvement among the genotypes. The present results are in conformity with earlier reports of Ghanshyam *et al.* (2015) [9], Nagar *et al.* (2019) [42] and Chaitanya *et al.* (2020) [3].

4.2 Estimates of genetic variability

The coefficient of genotypic and phenotypic variability is helpful to measure the extent of variability present in particular trait. They also provide a helpful measure to compare the variability present among various quantitative traits. The estimates of coefficient of variances revealed that magnitude of phenotypic coefficient of variation for all the traits were higher than the magnitude of genotypic coefficient of variation that indicated the role of environment in expression of traits. The estimate of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all traits. However, in general the results showed that for most of the characters studied in the present experiment, the magnitude of GCV was closer to the PCV (Chaudhary *et al*., 1987) [44].

High GCV and PCV was showed for number of umbels per plant, number of seeds per umbel, seed yield per plant (g), seed yield per plot (g) and (kg/ha), harvest index (%), essential oil (%), oleoresin (%), the estimates of PCV and GCV were close to each other. This indicated the role was played by genotype rather than environment and the characters having high genotypic coefficient of variation have better scope of improvement through selection. Similarly, Rawat *et al.* (2013) [24] noticed high GCV and PCV for the characters like yield per plant and seed yield per hectare in fennel. High magnitude of PCV and GCV for seed yield per plant of fennel was observed by Singh and Mittal (2002) [35]. Meena *et al.* (2013) [45] reported that PCV was slightly higher than corresponding GCV for umbels per plant and seed yield per plant in fennel.

Moderate GCV and PCV was observed for days to germination, test weight (g), number of branches per plant at 150 DAS and number of flowers per umbellates. Singh *et al*. (2019) [43] observed moderate GCV and PCV for test weight (g), umbellates per umbel and number of branches per plant. Similar results were reported by Dalkani *et al.* (2012) [46], Ravindrababu *et al.* (2012) [23], Meena *et al.* (2014) [17], Ghanshyam *et al.* (2015) [9], Meena and Dhakar (2017) [16], Nagar *et al.* (2019) [42] and Chaitanya *et al.* (2020) [3].

Low GCV and PCV was observed for plant height at 150 DAS, days to flower initiation (10%), days to 50 percent flowering, number of umbellates per umbel and days to physiological maturity. Ghanshyam *et al.* (2015) [9] and Chaitanya *et al.* (2020) [3] reported the low GCV and PCV for plant height at 150 DAS, number of umbellates per umbel, days to flower initiation (10%), days to 50 percent flowering DAS and physiological maturity. Lower values of GCV and PCV was recorded for number of umbellates per umbel indicating the important role of environment in the expression of the character and there was a least chance of improving these traits by direct visual selection. Other parameters like physiological maturity and days to 50 percent flowering exhibited low PCV and GCV indicating the narrow genetic base among the genotypes for a particular trait (Ghanshyam *et al.*, 2015) [9].

4.3 Estimation of heritability and genetic advance

Plant breeders are particularly interested in heritability as a measure of the value of selection for a certain trait in different types of progeny and as an indication of character transmissibility from parent to offspring. In order to assess the relative degree of the impact of genes and surroundings on overall phenotypic variability, it is crucial to understand the idea of heritability. Because of this, Burton (1952) [2] advocated taking into account both genetic variability and heritability when determining the full and precise impact of selection. The heritability estimates in broad sense were high for most of the characters (Table 3), it indicating that though the character is least influenced by the environment effects, the selection for improvement of such character may be useful, because broad sense heritability is based on total genetic variance which includes both fixable (additive) and non-fixable (dominance and epistatic variance).

High heritability was noticed for days to germination, number of branches per plant at 150 DAS, days to flower initiation (10%), days to 50 percent flowering, number of flowers per umbellates, number of umbels per plant, number of seeds per umbel, seed yield per plant (g), plant height at 150 DAS, days to physiological maturity, number of umbellates per umbel, seed yield per plot (g) and (kg/ha), harvest index (%), test weight (g), essential oil (%) and oleoresin (%). The present results are in conformity with earlier reports of by Meena *et al.* (2015) [47] and Dalkani *et al.* (2012) [46]. These results indicate that these traits are greatly governed by additive genes and therefore these characters can be readily fixed by selection. Similar reports also made by Patel *et al.* (2018) [20] and Rawat *et al.* (2013) [24] in fennel.

High genetic advance was noticed for number of branches per plant at 150 DAS, number of flowers per umbellates, number of umbels per plant, number of seeds per umbel, seed yield per plant (g), seed yield per plot (g) and (kg/ha), harvest index (%)**,** test weight (g), essential oil (%) and oleoresin (%). The present results are in conformity with earlier reports of Krishnamoorthy and Madalageri (2002) [14], Singh and Choudhary (2008) [30], Meena and Dhakar (2017) [16], Patel *et al.* (2018) [20], Nagar *et al.* (2019) [42] and Chaitanya *et al.* (2020) [3].

Moderate genetic advance over mean noticed for days to germination, plant height at 150 DAS, days to flower initiation (10%), days to 50 percent flowering and number of umbellates per umbel. The variability in these traits was due to both additive and non-additive gene action. Selection based on these traits was less effective in breeding programme. Low genetic advance over mean was noticed for days to physiological maturity. These characters were governed by non-additive gene action and selection based on these parameters found not effective. Prior research have reported by Sharma *et al.* (2015) [27], Meena and Dhakar (2017) [16], Patel *et al.* (2018) [20], Nagar *et al.* (2019) [42], Ranjeetha *et al.* (2020) [22] and Chaitanya *et al.* (2020) [3].

Low genetic advance over mean was noticed for days to physiological maturity. Meena *et al*. (2014) [17] and Dhakad *et al*. (2017) [7] reported the low genetic advance over mean for days to physiological maturity. These characters were governed by non-additive gene action and selection based on these parameters found not effective. Prior research have reported by Singh and Choudhary (2008) [30], Sharma *et al*. (2015) [27], Meena and Dhakar (2017) [16], Patel *et al*. (2018) [20], Nagar *et al.* (2019) [42], Ranjeetha *et al*. (2020) [22] and Chaitanya *et al.* (2020) [3].

High heritability accompanied with high genetic advance as percent of mean indicates that most likely the heritability is due to additive gene effects and selection may be effective, thus more emphasis should be given to mass selection and progeny selection for further improvement of these characters. However, it is not necessary that a character showing high heritability will also exhibit high genetic advance (Johnson *et al.*, 1955) [12].

4.4 Correlation and path analysis

Yield is the final product of various characters, which directly or indirectly influence the growth of plant. The correlation coefficient gives an idea about the various associations existing between the yield and yield components. It only reveals the direction and magnitude of association between any two characters but the path coefficient analysis helps in partitioning the correlation into direct and indirect effects of various yield and yield component. The theory of path coefficient for statistical analysis of causes and effects, which gives critical examination of specific forces to produce a correlation. Therefore, correlation studies coupled with path coefficient analysis are powerful tool to study the character association and their final impact on yields, which help the selection procedure accordingly (Singh *et al.* 2021) [32].

In the present investigation, at genotypic level and phenotypic level, significant to highly significant and positive association with yield was exhibited by harvest index (%)**,** number of umbels per plant, number of seeds per umbel, number of branches per plant at 150 DAS, number of flowers per umbellates, number of umbellates per umbel, essential oil (%), plant height at 150 DAS, oleoresin (%) and test weight (g). It was negatively and significantly associated with days to flower initiation (10%), days to 50 percent flowering and days to germination. The positive characters had significant correlation towards yield and all are considered as major yield contributing characters in ajwain. The results suggested that these traits can be utilized as selection indices for yield improvement in ajwain. Singh *et al.* (2006) [31-34] reported that seed yield was positively correlated with branches per plant and umbels per plant at genotypic level whereas negative correlation was observed with days to 50 percent flowering in coriander. According to Yadav *et al.* (2018) [39] seed yield was positively correlated with number of umbellets per umbel in fennel. These findings are in line with the reports of Sharma *et al.* (2015) [27], Meena and Dhakar (2017) [16], Shivaprasad *et* *al.* (2018) [28], Chaitanya *et al.* (2020) [3], Ranjeetha *et al.* (2020) [22] and Rawat *et al.* (2020) [24].

The concept of path coefficient analysis was originally developed by Wright (1921) [38], but the technique was first used for plant selection by Dewey and Lu (1959) [6]. Path analysis is simply standardized partials regression coefficient which splits the correlation coefficient into the measures of direct and indirect effects of a set of independent variables on the dependent variable. Phenotypic correlations of the characters were partitioned to path coefficient with a view to identify important component characters having direct effects on seed yield.

The path analysis revealed that the traits such as number of seeds per umbel followed by number of branches at 150 DAS, test weight (g), days to germination and oleoresin (%) had direct positive effect on seed yield per plant, whereas number of flowers per umbellates, harvest index (%), number of umbellates per umbel, days to 50 percent flowering, plant height at 150 DAS, number of umbels per plant, essential oil (%), and days to flower initiation (10%) had negative direct effect on total yield per plant. The results suggest that the above characters play a major role influencing the seed yield per plant both directly as well as indirectly through other yield parameters also. Hence, selection based on such characters would be effective in ajowan. This is in agreement with Kassahun *et al.* (2013) [13] who reported that seed yield per plant is an important character in making selection for seed yield per hectare in coriander. The present findings are supported by Lal *et al.* (2007) [15], Sharma *et al.* (2008) [26], Ghanshyam *et al*. (2015) [9] and Chaitanya *et al.* (2020) [3].

Table 1: Analysis of variance (ANOVA) for growth, yield and quality parameters in ajwain genotype (Pooled)

SN	Source of variation/character	Replication	Genotype	Error
	Degree of freedom	1	27	27
1	Days to germination	9.446	4.156**	0.817
2	Plant height at 150 DAS	11402.872	104.752**	36.569
3	Number of branches per plant at 150 DAS	20.190	6.312**	1.024
4	Days to flower initiation (10%)	0.540	128.556**	19.198
5	Days to 50 percent flowering	2.571	110.393**	23.340
6	Number of flowers per umbellates	9.364	22.450**	1.023
7	Number of umbels per plant	2411.719	8877.77**	58.569
8	Number of umbellates per umbel	2.122	3.167**	0.647
9	Number of seeds per umbel	306.704	6542.091**	476.551
10	Seed yield per plant (g)	1.605	8.167**	0.305
11	Harvest index (%)	37.294	77.454**	12.121
12	Test weight (g)	0.000	0.071	0.000
13	Essential oil (%)	0.000	0.386*	0.006
14	Oleoresin (%)	0.000	4.150**	0.004

**Significant at 1 (P=0.01) *Significant at 5 (P=0.05) DAS- Days after sowin

Table 2: Estimates of genetic parameters for different characters in ajwain genotype (Pooled)

SN	Range	Mean	GV	PV	GCV (%)	PCV (%)	Heritability (%)	GA	GAM (%)
1	9.75-15.5	12.43	1.67	2.08	10.40	11.60	80.30	2.39	19.20
2	66.23-96.83	84.11	34.09	52.38	6.94	8.60	65.10	9.70	11.54
3	10.25-18.18	14.86	2.64	3.16	10.94	11.95	83.80	3.07	20.63
4	66.00-101.50	87.58	54.68	64.28	8.44	9.15	85.10	14.05	16.04
5	77.25-109.75	96.36	43.53	55.20	6.85	7.71	78.90	12.07	12.53
6	11.80-23.85	16.93	10.71	11.23	19.33	19.79	95.40	6.59	38.90
7	129.75-156.00	138.56	38.08	48.82	4.45	5.04	78.00	11.22	8.10
8	75.68-289.90	149.36	4409.60	4438.89	44.46	44.61	99.30	136.34	91.28
9	9.38-14.90	11.81	1.26	1.58	9.50	10.65	79.60	2.06	17.46
10	67.70-280.00	150.06	3032.77	3271.05	36.70	38.11	92.70	109.24	72.80
11	4.93-11.96	7.49	3.93	4.08	26.46	26.97	96.30	4.01	53.48
12	118.25-374.63	214.93	4724.92	5144.21	31.98	33.37	91.80	135.70	63.14
13	220.95-711.79	409.61	17327.73	19047.67	32.13	33.69	91.00	258.64	63.14
14	14.83-32.90	22.52	32.67	38.73	25.38	27.64	84.40	10.81	48.02
15	0.97-1.83	1.31	0.04	0.04	14.27	14.29	99.70	0.39	29.34
16	0.90-2.30	1.64	0.19	0.19	26.67	26.87	98.50	0.89	54.52
17	1.75-6.65	4.26	2.07	2.08	33.83	33.84	99.90	2.97	69.65

GCV- Genotypic coefficient of variation PCV- Phenotypic coefficient of variation GA- Genetic advance GAM- Genetic advance over mean

1. Days to germination
2. Plant height (cm) at 150 DAS
3. Number of branches per plant at 150 DAS
4. Days to flower initiation (10%)
5. Days to 50 percent flowering
6. Number of flowers per umbellates
7. Days to physiological maturity
8. Number of umbels per plant
9. Number of umbellates per umbel
10. Number of seeds per umbel
11. Seed yield per plant (g)
12. Seed yield per plot (g)
13. Seed yield per plot (kg/ha)
14. Harvest index (%)
15. Test weight (g)
16. Essential oil (%)
17. Oleoresin (%)

Table 3: Genotypic correlation for yield and yield related traits in ajwain genotype (Pooled)

@	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1.000	-0.982**	-0.989**	0.790**	0.858**	-0.756**	-0.779**	-0.789**	-0.891**	-0.914**	-0.438**	-0.844**	-0.627**	-0.809**
X2		1.000	0.975**	-0.999**	-0.934**	0.827**	0.805**	0.678**	0.908**	0.871**	0.169	0.898**	0.498**	0.842**
X3			1.000	-0.890**	-0.959**	0.841**	0.863**	0.867**	0.863**	0.863**	0.205	0.841**	0.420**	0.892**
X4				1.000	0.956**	-0.829**	-0.929**	-0.786**	-0.924**	-0.988**	-0.363**	-0.624**	-0.541**	-0.881**

X5					1.000	-0.855**	-0.938**	-0.673**	-0.960**	-0.766**	-0.358**	-0.610**	-0.619**	-0.907**
X6						1.000	0.885**	0.798**	0.958**	0.879**	0.289*	0.641**	0.322*	0.912**
X7							1.000	0.940**	0.951**	0.957**	0.390**	0.641**	0.351**	0.965**
X8								1.000	0.902**	0.858**	0.471**	0.780**	0.478**	0.844**
X9									1.000	0.932**	0.383**	0.738**	0.359**	0.950**
X10										1.000	0.467**	0.693**	0.518**	0.971**
X11											1.000	0.370**	0.162	0.461**
X12												1.000	0.251	0.650**
X13													1.000	0.325*

Critical value of 'r' at 5%= .2631 and that at 1% = .3415 ** Significant at 1 percent level of probability * Significant at 5 percent level of probability

X1- Days to germination
X2 - Plant height (cm) at 150 DAS
X3 - Number of branches per plant at 150 DAS
X4 - Days to flower initiation (10%)
X5 - Days to 50 percent flowering
X6 - Number of flowers per umbellates
X7 - Number of umbels per plant
X8 - Number of umbellates per umbel
X9 - Number of seeds per umbel
X10 - Harvest index (%)
X11- Test weight (g)
X12- Essential oil (%)
X13 - Oleoresin (%)
X14 - Seed yield of a plant (g)

Table 4: Phenotypic correlation for yield and yield related traits in ajwain genotype (Pooled)

@	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1.000	-0.505**	-0.599**	0.642**	0.644**	-0.581**	-0.618**	-0.651**	-0.618**	-0.612**	-0.358**	-0.711**	-0.514**	-0.629**
X2		1.000	0.768**	-0.645**	-0.644**	0.636**	0.590**	0.608**	0.649**	0.594**	0.120	0.567**	0.350**	0.581**
X3			1.000	-0.694**	-0.686**	0.754**	0.763**	0.689**	0.775**	0.675**	0.182	0.688**	0.354**	0.755**
X4				1.000	0.971**	-0.666**	-0.798**	-0.707**	-0.710**	-0.674**	-0.313*	-0.554**	-0.461**	-0.724**
X5					1.000	-0.634**	-0.755**	-0.696**	-0.677**	-0.634**	-0.289*	-0.524**	-0.492**	-0.685**
X6						1.000	0.842**	0.717**	0.940**	0.802**	0.278*	0.588**	0.311*	0.879**
X7							1.000	0.767**	0.881**	0.813**	0.387**	0.630**	0.348**	0.922**
X8								1.000	0.847**	0.791**	0.371**	0.637**	0.391**	0.774**
X9									1.000	0.864**	0.355**	0.660**	0.339*	0.910**
X10										1.000	0.403**	0.583**	0.444**	0.925**
X11											1.000	0.360**	0.160	0.441**
X12												1.000	0.245	0.618**
X13													1.000	0.314*

Critical value of 'r' at 5%= .2631 and that at 1%= .3415 ** Significant at 1 percent level of probability * Significant at 5 percent level of probability

X1- Days to germination
X2 - Plant height (cm) at 150 DAS
X3 - Number of branches per plant at 150 DAS
X4 - Days to flower initiation (10%)
X5 - Days to 50 percent flowering
X6 - Number of flowers per umbellates
X7 - Number of umbels per plant
X8 - Number of umbellates per umbel
X9 - Number of seeds per umbel
X10- Harvest index (%)
X11- Test weight (g)
X12- Essential oil (%)
X13 -Oleoresin (%)
X14 -Seed yield of a plant (g)

Table 5: Genotypic path for yield and yield related traits in ajwain genotype (Pooled)

@	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	rG
X1	0.531	0.670	-2.010	-0.135	-0.721	1.071	0.423	1.033	-2.707	0.946	-0.248	0.373	-0.035	-0.809**
X2	-0.611	-0.582	1.983	0.180	0.942	-1.171	-0.437	-1.047	2.759	-0.901	0.096	-0.397	0.028	0.842**
X3	-0.525	-0.567	2.033	0.152	0.806	-1.190	-0.469	-0.846	2.622	-0.893	0.116	-0.372	0.023	0.892**
X4	0.420	0.615	-1.810	-0.171	-0.847	1.174	0.505	0.980	-2.809	1.022	-0.205	0.276	-0.030	-0.881**
X5	0.455	0.652	-1.950	-0.172	-0.841	1.210	0.509	1.058	-2.917	1.056	-0.202	0.269	-0.035	-0.907**
X6	-0.401	-0.481	1.709	0.141	0.719	-1.416	-0.480	-0.779	2.912	-0.910	0.164	-0.283	0.018	0.912**
X7	-0.413	-0.468	1.754	0.158	0.788	-1.252	-0.543	-0.917	2.892	-0.991	0.221	-0.283	0.020	0.965**
X8	-0.562	-0.624	1.762	0.171	0.911	-1.130	-0.510	-0.976	2.741	-0.888	0.267	-0.344	0.027	0.844**
X9	-0.473	-0.528	1.754	0.158	0.807	-1.356	-0.517	-0.880	3.040	-0.965	0.217	-0.326	0.020	0.950**
X10	-0.485	-0.506	1.754	0.168	0.857	-1.245	-0.520	-0.837	2.833	-1.035	0.264	-0.306	0.029	0.971**
X11	-0.232	-0.098	0.418	0.062	0.301	-0.410	-0.212	-0.460	1.165	-0.483	0.566	-0.163	0.009	0.461**
X12	-0.448	-0.522	1.710	0.106	0.513	-0.907	-0.348	-0.761	2.244	-0.717	0.209	-0.442	0.014	0.650**
X13	-0.333	-0.289	0.854	0.092	0.521	-0.455	-0.190	-0.467	1.092	-0.536	0.091	-0.111	0.056	0.325*

rG- Genotypic correlation value of seed yield/plant ** Significant at 1 percent level of probability * Significant at 5 percent level of probability

X1- Days to germination
X2 - Plant height (cm) at 150 DAS
X3 - Number of branches per plant at 150 DAS
X4 - Days to flower initiation (10%)
X5 - Days to 50 percent flowering
X6 - Number of flowers per umbellates
X7 - Number of umbels per plant
X8 - Number of umbellates per umbe
X9 - Number of seeds per umbel
X10 - Harvest index (%)
X11- Test weight (g)
X12- Essential oil (%)
X13 - Oleoresin (%)
X14 - Seed yield of a plant (g)

5. Conclusion

The analysis of variance showed highly significant differences among the genotypes for all the parameters. The characters like number of branches per plant at 150 DAS, number of flowers per umbellates, number of umbels per plant, number of seeds per umbel, seed yield per plant (g), seed yield per plot (g) and (kg/ha), harvest index (%), test weight (g), essential oil (%) and oleoresin (%) had high estimates of all variability parameters. From the study of character association ships, among the correlation analysis the characters namely, harvest index (%), number of umbels per plant, number of seeds per umbel, number of branches per plant at 150 DAS, number of flowers per umbellates, number of umbellates per umbel, essential oil (%), plant height at 150 DAS, oleoresin (%) and test weight (g) have positive correlation and the path analysis revealed that the traits such as number of seeds per umbel followed by number of branches at 150 DAS, test weight (g), days to germination and oleoresin (%) had direct positive effect on seed yield per plant. sBy this study, we believe that the findings will provide a valuable basis for future ajwain breeding programs and the development of high-yielding ajwain variety

6. Author Contributions

All authors have helped and supported to me in writing the manuscript and agreed to the published version of the manuscript.

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8. Conflicts of Interest

The authors declare no conflict of interest.

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