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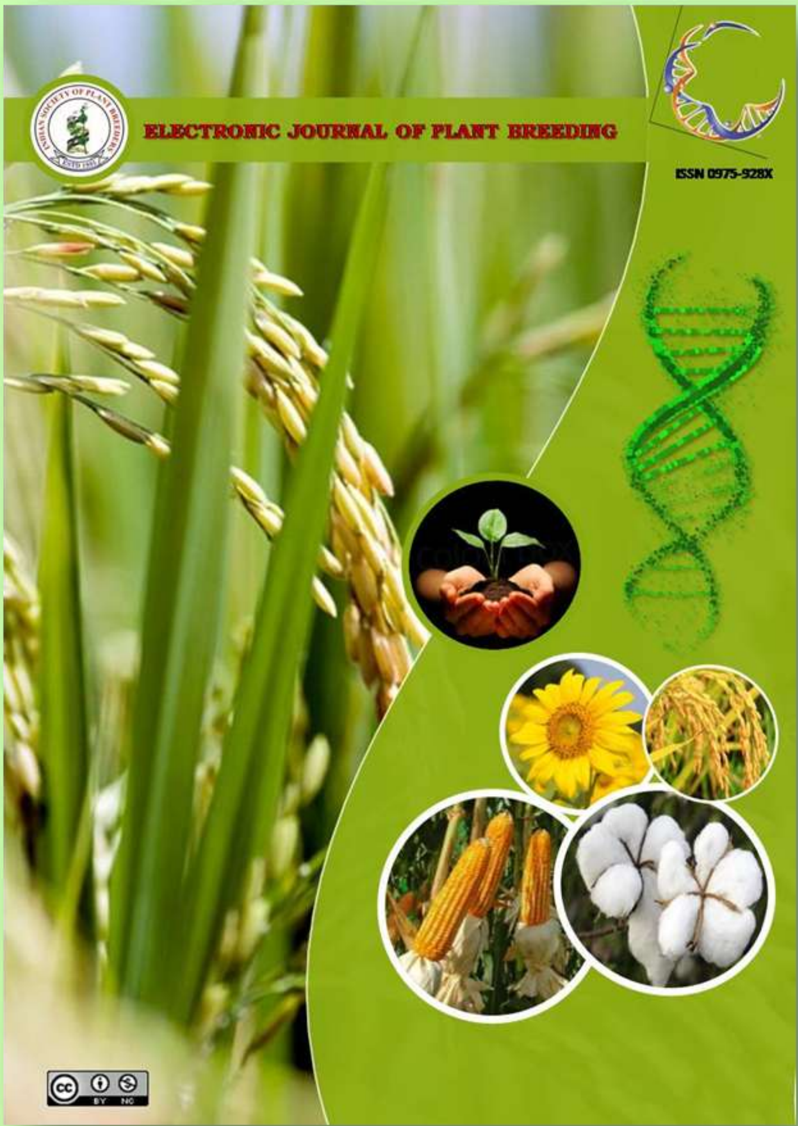

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Research Article

Stability analysis for seed yield and yield component traits in ajwain (*Trachyspermum ammi* L.)

Monika Meena[1], Indu Rialch[3], Arun Kumar[2], R.B. Dubey[1], Baudh Bharti[1]* and N. S. Dodiya[1]
[1]Department of Plant Breeding & Genetics, Maharana Pratap University of Agriculture and Technology, Udaipur-313001(Rajasthan), India
[2]Department of Genetics & Plant Breeding, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar-263145, Uttarakhand
[3]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, Punjab-141004
***E-Mail** : baudhbhartigpb@gmail.com

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Abstract
Genetic improvement toward optimized and stable agronomic performance of ajwain genotypes is desirable for food security. Understanding how genotypes perform in different environmental conditions helps breeders develop sustainable cultivars adapted to target regions. Complex traits of importance are known to be controlled by a large number of genomic regions with small effects whose magnitude and direction are modulated by environmental factors. Knowledge of the constraints and undesirable effects resulting from genotype by environmental interactions is a key objective in improving selection procedures in ajwain breeding programs. The mean squares due to genotypes x environment G x E (L) interactions were also significant for all the characters except day to 50% flowering and days to 75% maturity, plant height and test weight . The genotypes UA-63 was superior in per se performance and stability for seed yield seed yield suggesting its suitability for inclusion in future breeding programme for development of stable variety. The genotype UA-48 found suitable for high yielding environments, while genotypes, UA-66, UA-7, UA-83, UA-29, UA-70, UA-71, Local check, UA-41, UA-28, UA-30, UA-90, UA-1, UA-32, UA-87 and GA-1were best in poor environments for seed yield.

Key words
Eberhart and Russel stability index, GGE, seed yield, ajwain genotype

Introduction

Ajwain (*Trachyspermum ammi* L.) well known as carum seed or Bishop's weed belongs to family Apiaceae and is a native of Egypt. It is a popular minor seed spice crop having good medicinal value in India. The flowers are protandrous and cross-pollination occurs through insects (Malhotra and Vijay 2004). Usually grayish brown seeds or fruits of Ajwain are used for medical and nutritional purposes (Chauhan *et al.* 2012). Ajwain has been commonly used in traditional medicine systems for a cultivar of medicinal and pharmacological aspects (Lateef *et al.* 2006). A number of chemical constituents have been reported for the herb. Phytochemical constituents of Ajwain are; fiber (11.9%), carbohydrates (24.6%), tannins, glycosides, moisture (8.9%), protein (17.1%), fat (21.1%), saponins, flavones and other components (7.1%) constituting calcium, phosphorous, iron, cobalt, copper, iodine, manganese, thiamine, riboflavin and nicotinic acid(Qureshi and Kumar 2010 and Ranjan *et al.* 2012). In the alcoholic extraction process, a large amount of saponin has been derived (Ranjan *et al.* 2012). Traditional practitioners recommended the herb as a digestive stimulant medicine (Aghili *et al.* 1992). Genetic differences do exist among cultivars-cultivars for yield stability. Genotype by environment interaction creates problems in identifying superior genotypes (Allard and Bradshaw, 1964). One of the objectives of plant breeders is to develop cultivars that are high yielding across extensive range of environmental conditions. However, the presence of genotype-by-environment interactions (GEI) (Crossa 1990; Kang 1997; Zobel *et al.* 1988) can complicate this outcome. For example, the GEI of a crossover type causes changes in ranking performance across environments, complicating the breeders' task of selecting best candidate genotypes for next improvement cycle.

Crop performance depends upon the genotype, environment and their interaction. To select broadly adapted and stable genotypes, information dealing with adaptation of cultivar and stability over environments (locations and years) is important. The behavior of cultivars in distinct environments is of special interest in breeding efforts targeting complex traits, such as seed yield, which are controlled by a large number of alleles, mostly presenting small effects, but which are very responsive to the environment (Des Marais *et al*. 2013; Xavier *et al*. 2016). Identification of stable genotypes that show the least GE interaction is an important consideration in sites with noticeable environmental fluctuations.

Yield stability is the ability of a genotype to avoid significant fluctuation in yield over a range of environmental conditions (Heinrich *et al*. 1983). However, responsiveness to advances in the agronomic improvement of a production environment is also an important aspect in breeding, which describes the cultivar's ability to react to the change in the environmental conditions. One of the basic components for characterization of the plant genotype is the estimation of the productivity for stability and adaptability (Raj *et al*. 1997) which is often expressed by realized yield (Stoffella *et al*, 1984, Becker and Leon, 1988 and Kang, 1997). When significant, GEI has an important role in accounting for the phenotypic variation of quantitative traits and can be accommodated in statistical models designed for multi-environmental trials (Cooper *et al*. 1996). Stability indices allow researchers to identify widely adapted genotypes for using in breeding programs and help improving recommendations to the growers (Mohebodini *et al*. 2006).

Many breeders have used the (Eberhart and Russel (1966) approach of joint linear regression analysis to assess GEI, by plotting the individual genotypic regression coefficients (i.e., genotypic response to a linear array of environmental productivities) against the genotypic means over all environments to interpret the results (Figure 3). Genotypes with more "stability" have regression coefficients of less than unity, which is consistent with these genotypes performing well in low productivity environments, but also performing poorly in high productivity environments. Genotypes with regression coefficients >1 are more sensitive to environmental changes, thus the environmental conditions have a greater influence on their performance than the genotypes that have regression coefficients closer to zero. Therefore in the present study, an attempt was made to collect the information as to whether genotypes of Ajwain respond differentially when grown at different times and if they do so, how important the GxE interactions are for seed yield and its components. Characterization of genotype-environment interaction in Ajwain would be immensely helpful if estimated over prevalent agricultural practices. This would lead to successful evaluation and development of phenotypically stable and superior cultivars which are usually sought for commercial production.

Material and Methods

Twenty eight diverse genotypes of ajwain (Fig.1) were evaluated under four different environments *viz.*, E_1 (late *khari*f, during 2013-14 at Udaipur), E_2 (late *khari*f, during, 2013-14 at Pratapgarh), E_3 (late *kharif*, during 2014-15 at Udaipur) and E_4 (late *kharif*, during 2014-15 at Pratapgarh) in Randomized Block Design with three replications. Each genotype was sown in four-row plot of 3.0 m row length. Row to row and plant-to-plant distance was maintained as 30 cm and 10 cm at each location, respectively. All the recommended agronomical practices and plant protection measures were adopted to raise a healthy crop to attain maturity. Fertilizers were applied @ 20 kg N: 20 kg P_2O_5 at the time of sowing as basal dose while 20 kg N/ha was top-dressed in two split doses in thirty and sixty days respectively. Crop was irrigated 6 times during the crop season. First irrigation was given immediately after sowing and there after irrigation was given at an interval of 20-25 days. The observations were recorded on ten randomly selected plants of each genotype in each replication for each environment for 11 quantitative traits *viz.,* plant height, number of primary branches per plant, number of umbels per plant, number of umbelets per umbel, number of seeds per umbelets, biological yield per plant, seed yield per plant, test weight and oil content. However, days to 50% flowering and days to 75% maturity were recorded on plot basis, while oil content was estimated by using AOAC (1965) and average pooled mean values were used for statistical analysis. Stability analysis was carried out as per Eberhart and Russell (1966) model for all the observed traits.

Result and Discussion

The mean squares due to phenotypic stability with regards to different traits on the basis of pooled data are presented in (Table-1). Mean squares due to genotypes, environment (E) plus genotypes x environment (G x E) interaction, genotype x environment (Lin.) were significant for all the characters studied. except day to 50% flowering and days to 75% maturity due to genotypes and day to 50% flowering and days to 75% maturity, plant height and Test weight (g) due to environment (E) plus genotypes x environment (G x E) and genotype x environment (Lin.). Significant G × E (linear) for different traits has been reported by Kole 2005 and Lal (2008). The significant mean squares due to pooled deviation for number of umbels per plant and Oil content (%) indicated that the genotypes differed considerably with respect to their stability and prediction for these traits would be difficult. Significant deviations from regression have been reported earlier also by Tomer *et al*.(2004) and Verma *et al.(*2014).

Cultivars characterised by regression coefficient (bi) of the order of 1.0 have average stability over all the environments, regression coefficient (bi) >1 have below average stability for favourable environments and on the other hand regression coefficient (bi) <1 have above average stability for unfavourable environments. The three important parameters in this analysis are regression coefficient (bi), deviation from regression (S^2di) and cultivars' mean yield over all the environments. To summarize regression coefficient (bi) of approximately 1.0 indicates average stability. When this is associated with high mean yield and non-significant deviation from regression (S^2di) cultivars have general adaptability; when associated with low mean yield the cultivars are poorly adopted to all the environments. Regression values increasing above 1.0 describe cultivars with increasing sensitivity to environmental changes (below average stability) and greater specificity of adaptability to higher yielding environments. Similarly regression values decreasing below 1.0 provided a measure of grater resistance to environmental changes (above average stability), and therefore increasing specificity of adoptability to low- yielding environments (Fig-3).

A simultaneously consideration of all the three parameters (X, bi and S^2di) showed that only genotype UA-63 had high seed yield and test weight, regression coefficient around unity (b = 1) and non significant deviation from regression (S^2di) indicating that this genotype was most adaptable and stable in varying environmental conditions (Table 2). Genotype UA-48 owing its recorded high seed yield (11.75g) against 11.14g of the population mean, regression value more than one and deviation from regression least and non-significant, appeared to be suitable under rich environment. This is also suitable for other traits like biological yield per plant, seeds per umbelet, test weight, plant height and day to 50% flowering . In addition to this UA-7 for number of primary branches, number of umbelets per umbel and biological yield per plant (g): UA-32 for days to 75% maturity, number of umbelets per umbel, seeds per umbelet, test weight (g) and oil content (%) also fell under this group. Further, this is suggested that these genotypes could be recommended for timely sown conditions. Similar results reported by Lal (2008) and Verma *et al.(*2014). The cultivar UA-66 appeared to be suitable in low yielding environment. There stability parameters were of high mean, bi < 1 and least S^2di for seed yield per plant, test weight, oil content, biological yield per plant (g) and number of umbelets per umbel. Similarly cultivar UA-29 for seed yield per plant, test weight, biological yield per plant and plant height. The cultivar UA-71 for for seed yield per plant, test weight, biological yield per plant. This is suggested that these genotypes could be recommended for late sown conditions. The results confirmed the findings of Basu *et al*. (2009), Gangopadhyay *et al.* (2012).

Stability analysis can aid plant breeders in the selection procedure, and give cultivar recommendations. The success of stability analysis, and the proportion of the phenotypic variability explained by GEI, can be influenced by genotypes. The genotypes was UA-63 superior in *per se* performance and stability for seed yield suggesting its suitability for inclusion in future breeding programme for development of a stable cultivar. The genotypes UA-48 was found suitable for high yielding environments, while genotypes, UA-66, UA-7, UA-83, UA-29, UA-70, UA-71, Local check, UA-41, UA-28, UA-30, UA-90, UA-1, UA-32, UA-87 and GA-1 were best in poor environments for seed yield.

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Table 1. Analysis of variance of phenotypic stability for different characters studied in Ajwain (Eberhart and Russell, 1966)

Characters	Genotype [27]	E+(G x E) [84]	E (L) [1]	G x E (L) [27]	Pool dev. [56]	Pool Err [216]
Day to 50% flowering	3.15	1.07	0.01	0.72	1.26	7.20
Days to 75% maturity	9.45	3.37	0.24	9.01	0.71	36.19
Plant height (cm)	40.30**	6.94	0.03	7.44	6.83	11.71
No of primary branches	1.48**	1.30**	0.09	3.45**	0.13	0.11
No of umbels per plant	606.62**	142.91**	0.51	252.52**	92.60**	23.95
No of umbelets per umbel	1.613**	1.50**	0.09	4.15**	0.24	0.18
Seeds per umbelet	14.59**	1.34**	0.08	3.97**	0.10	0.74
Biological yield per plant (g)	8.45**	0.98	0.08	1.75*	0.64	1.05
Seed yield per plant (g)	2.55**	0.47**	0.01	0.99**	0.23	0.17
Test weight (g)	0.01**	0.00	0.00	0.00	0.00	0.00
Oil content (%)	1.17**	0.10**	0.01	0.25**	0.03**	0.02

*,** significant at 5% and 1% level, respectively

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Table 2. Ajwain genotypes classified with respect to their adaptability in different type of environments

Characters	Genotypes suited to different type of environments		
	High mean performance, above average response (bi > 1) suited in favourable environment	High mean performance, average response (bi =1) general adaptation	High mean performance, below average response (bi <1) suited in poor environment
Day to 50% flowering	UA-41, UA-127, UA-90, UA-175, UA-30, UA-141, UA-48 and UA-149	UA-131	UA-53, UA-168 and UA-28
Days to 75% maturity	UA-113, UA-32, UA-127, UA-41, UA-66, UA-53 and UA-141	UA-87, UA-125, and UA-29	Local check, GA-1 and UA-1
Plant height	UA-70, UA-28, UA-87, UA-48, UA-1 and UA-127,	-	UA-29, UA-90, UA-30, UA-125, UA-63, UA-53, UA-7, UA-175 and UA-41
No of primary branches	UA-7, UA-90, GA-1, UA-149, UA-113, UA-83, UA-168 and UA-175	Local check	UA-30, UA-32, UA-28, UA-141, UA-48, UA-41, UA-127 and UA-53
No of umbels per plant	UA-149, UA-175 and UA-169	-	GA-1, UA-1, UA-32, Local check, UA-191 and UA-48
No of umbelets per umbel	UA-87, UA-32, UA-63, Local check. UA-7, UA-90 and UA-127	UA-191 and UA-168	UA-53, UA-1, UA-131, UA-169, UA-66, UA-149 and UA-175
Seeds per umbelet	UA-41, UA-149, UA-32, UA-90, UA-113, UA-125 and UA-48	-	GA-1, Local check, UA-191, UA-175, UA-169, UA-141, UA-127, UA-131, UA-1, UA-63, UA-87 and UA-168
Biological yield per plant (g)	UA-1, UA-63, UA-7 and UA-48	UA-70	UA-66, Local check, UA-29, UA-83, UA-71, UA-41, UA-28, UA-30, UA-90, UA-32, UA-87 and GA-1
Seed yield per plant (g)	UA-48	UA-63	UA-66, UA-7, UA-83, UA-29, UA-70, UA-71, Local check, UA-41, UA-28, UA-30, UA-90, UA-1, UA-32, UA-87 and GA-1
Test weight (g)	UA-32, UA-48, UA-127, UA-149 and UA-113	UA-7, UA-53, UA-63 and UA-70	UA-28, UA-29, UA-30, UA-41, UA-66, UA-71, UA-83, UA-87, UA-90, UA-125, UA-131, UA-141, UA-168, UA-169, UA-175, UA-191, GA-1, UA-1 and Local check
Oil content (%)	UA-32, GA-1, UA-29 and UA-7	-	UA-191, UA-70, UA-125, UA-1, UA-28, UA-175, UA-90, UA-66 and UA-53

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