Evaluation of the Salinity Stress Effect on Cumin (Cuminum cyminum L.) Ecotypes in Kerman, Iran

Mahla Samareh Saliani¹ and Alireza Bahraminejad²*

¹Master of Science in Physiology and Breeding of Herbal Plants, Islamic Azad University Jiroft Branch, Iran.
²Department of Plant Production, Islamic Azad University Zarand Branch, Zarand, P.O.B. 776146595, Kerman, Iran.

Authors' contributions

This work was carried out in collaboration between both authors. Author AB designed the study, wrote the protocol and interpreted the data. Author MS anchored the field study, gathered the initial data and performed preliminary data analysis. Authors while AB and MS managed the literature searches and produced the initial draft. Both authors read and approved the final manuscript.

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ABSTRACT

Cumin (Cuminum cyminum L.) is one of the most important Medicinal plants. Since many semi arid and arid areas of Iran are affected by salinity and accessing water resources has been decreased. Proper measures need to be taken for water efficiency and efficient use of salt area in agriculture. Resources can be used in an optimum way by changing the planting pattern and using proper of cumin under salt stress. This research was conducted to determine the highest rate yield and tolerance against salinity stress of different ecotypes of cumin. The experiment was executed in the triple lattice with three repetitions in Kerman, Iran. The results showed that salinity stress has significant deference on traits such as seed index, seed yield, dry weight and harvest index, while it has non-significant result on other yield components such as plant height, number of umbel per plant, number of seeds per umbel and number of seeds per plant. The studied ecotypes had a significant difference regarding all of the characteristics. Therefore, the ecotype of Sepidan from Pars province was identified as the most tolerating and the ecotype of Qaen from Southern-
Khorasan province was identified as the most sensitive ecotype under salinity stress regarding seed yield.

Keywords: Cumin; ecotypes; salinity stress; yield component.

1. INTRODUCTION

Cumin belonging to *umbelliferae*, is an annual plant and one of the most important and oldest spice seed that has been used by humans. Economic value of cumin is the numerous uses of the seeds as a drug and spicy for about a thousand years ago [1]. It is regarded as part of food cultures in West Asia, a predominant habitat of this plant. Therefore, trade and consumption of the crop is almost limited to natural areas that product it [2]. In recent years cumin has been attended by farmers due to the low water requirement, tolerance to salinity and short growing season and according to the great importance of this plant and its growing cultivation, determination of the appropriate amount for each environment can worthy help this affair [3]. Salinity stress is the accumulation of soluble salts in the plowing's depth or around plant's roots to the extent that damage the plant growth and the product or destroy the plant. Salinity stress is one of the most extensive damage that is in desert and semi-desert areas due to salt accumulation, wetlands and coastal areas due to sea progression as well as soils with poor drainage. Plants growth under salt stress may be decrease with changes in osmotic potential due to low water potential in the root environment or the effects of specific ions [4]. Gory et al. [5] have tried to irrigate cumin plants with water which has 0, 4, 12 and 16 dS/m salinity. In this experiment, the higher salinity above 8 dS/m causes significant decreasing in performance. Moreover, Zidan and Elewa [6] analyzed the salinity effects caused by sodium chloride at levels of zero, 40, 80, 120, 160, 200, 240 and 280 mM on cumin germination and seedling growth characteristics in cumin and founded that germination was reduced greatly in high levels of salinity. Salt stress with NaCl, 40 and 80 mM decreased shoot and root length. Treatment with200 mM showed the significant decreasing in the shoot, root and dry weight. Nabizadeh et al. [7] reported that salinity below 50 mmol has no any effect on vegetative characteristics of cumin. There are many semi arid and arid regions of Iran are affected by salinity and also since accessing water resources has been declined, proper measures should be taken for water efficiency and efficient use of salt region in agriculture. Resources can be used in an optimum way by changing the planting model and using proper herbs that can tolerate salinity stress. This study was executed to determine the most rate yield and endurance against salinity stress of different ecotypes of cumin.

2. MATERIALS AND METHODS

Forty nine cumin ecotypes which they are subpopulations belonged to nine populations from different provinces of Iran that has the biggest variation for cumin (Table 1) [1]. It was laid out in a simple lattice design with two replications in the Agricultural Research field in Kerman (30°18’ N, 57°6’ E and 1754 AMSL) in 2013-2014. After preparation of soil and planting seeds, the field was irrigated by salty water in treatments of salinity and ordinary water in the control treatment. The genotypes were planted in plots of 4 m long. There was 50 cm row spacing and the distance between plants was 5cm. All experimental plots were treated uniformly.

2.1 Irrigation in Normal and Saline Environment

The First irrigation before planting was heavy. The second irrigation was performed just after planting and style. Supplemental irrigation during the growing season was done after 8 days and the last irrigation was performed 2 weeks before harvest. It was irrigated by natural saline water with pH 7.6 and conductivity equal to 3.55 dS/m. Plants were harvested after removal of edge effect, for measuring the traits 20 plants were selected. Characterizations such as plant height, number of seeds per umbel, number of umbels per plant, seed weight, seed yield, dry weight and harvest index were recorded.

2.2 Statistical Analysis

All data were subjected to analysis of variance (ANOVA) using SAS statistical software version 9 (SAS Institute Inc., Cary, NC, USA) and means were compared using Duncan significant difference test (HSD) at alpha 0.05 and Excel software.
3. RESULTS AND DISCUSSION

3.1 Plant Height

The results of variance analysis showed that the effect of the environment on plant height wasn’t significant. But ecotype interaction with the environment on plant height was highly significant (Table 1). The mean compression results of the ecotype plant height effect showed the maximum height 19.55 cm in Jat and the minimum height 10.95 cm in Feridan ecotypes. It could be due to application of salinity stress after full deployment of plant. Therefore, at this stage, plant almost was done. Its length growth and has not apical meristem growth and its length growth is just for the internodes [8]. The mean environment interaction with ecotype examined environment without stress, Sorkheh with 20.80 cm and Feridan ecotypes with 10.90 cm had the highest and lowest height respectively. In stress environment, ecotypes as Sarvestan and Sirjan had the heights with 22.80 cm and the lowest with 10.40 cm plant height (Table 3). Zidan and Elewa [6] reported below 80 mM of salinity plant height of cumin increased.

3.2 Umbel Per Plant

According to the analysis of variance, there was no significant effect of environment on umbels per plant. The ecotype and environment interaction effects were highly significant (Table 1). The mean comparison results indicated the ecotype effect due to the lack of a significant the number of umbels per plant ecotypes as Aq-Qala with 32.4 was the highest number of umbel per plant and Taybad with 7.5 had the highest number of umbel per plant. Mean Comparison results of environment with ecotype interaction showed that different ecotypes in salinity stress presented different reactions and also the number of umbel plant compared with two environments had a significant difference. Non stress environment Ardestan and Sadoq ecotypes had the highest and the lowest number umbel per plant with an average of 109 and 7 respectively. In salt stress environment, Aq-Qala ecotype with an average of 46.70 had the most and Sirjan ecotype with an average of 5.70 had the lowest number of umbel per plant (Table 3). Gory et al. [5] reported that salinity less than 8 dS/m has no significant effect on the components. The number of umbel per plant explained just about 96% of yield variation [9]. So, the increasing number of umbels in stress environment compared to no stress environment in different ecotypes is due to genetic differences which showed different responses.

3.3 Number of Seed Per Umbel

According to Table (1), results indicated that the environment has no significant effect on seed per umbel. However, the interactions between tested ecotypes and environment with ecotype were significant difference. Mean Comparison of ecotypes on number of seed per umbel showed that Sadoq and Maraveh-Tapeh ecotypes with an average of 9.55 had the most and Estahban with an average of 5.50 had the least number of seed per umbel. Reduction of umbel per plant increases the contribution of each umbel from Photosynthesis materials and it will increase the number of seeds per umbel [10]. In Stresses environment, Sadoq and Zarand ecotypes with averages of 10.60 and 5.40 were the most and least seed per umbel, respectively (Table 3). Kafi and Keshmehr [11] reported with increasing salinity, number of seed per umbel reduces. Moreover, Gory et al. [6] showed that the salinity less than 8 dS/m had no significant effect on the number of seeds per umbel.

3.4 Number of Seed Per Plant

The results of variance analysis showed that there was no significant effect of the environment on number of seed per plant. But ecotype interaction with the environment on number of seed per plant was highly significant (Table 1). The mean comparison results indicated the ecotype effect due to the lack of a significant the number of seed per plant ecotypes as Aq-Qala and Taybad with 283.85 and 52.70 had the highest and lowest number of seed per plant, respectively. On stress environment Zarand ecotype had the highest and Taybad and Baneh ecotypes had the lowest number seed per plant with an average of 206.6 and 53.6 respectively. In salt stress environment, Aq-Qala ecotype with an average of 416.2 had the most and Sirjan ecotype with an average of 38.30 had the lowest number of seed per plant (Table 3). Gory et al. [5] reported that salinity less than 8 ds/m and also Armin et al. [12] the salinity less than 6 µmhos/m had any effect on cumin yield components. The cause of increase in the number of seeds from per plant ecotype in stress compared to without stress environment might be the genetic salt tolerant of ecotype.
3.5 Seed Weight Index

The results of seed weight index showed that the effect of the environment on this trait is very meaningful and stress had significant deference on seed weight index. Moreover, environment with ecotype interaction was a highly significant difference (Table 1). According to the results of the mean comparison for environment effect on seed weight index exhibited Natanz with mean 0.3885g and Banah ecotypes with mean of 0.2605 g had the highest and the lowest seed weight. Results of mean Comparison indicated environment with ecotype interaction in non-stress environment with an average of 0.4200 g in Natanz is the maximum and Birjand ecotype with an average of 0.2550 g was minimum seed weight index. However, ecotypes of Qaen and Taybad with averages of 0.4110 and 0.2530 g were the highest and the lowest seed weight index in salinity environment, respectively (Table 3). The Latest part of yield is seed weight index in cumin that influenced by genetic factors [13]. Kafi and Keshmiri [11] reported that, increasing salinity reduces seed weight index. But Armin et al. [13] stated that the salinity less than 6 µmhos/m has no effect on seed weight index.

3.6 Seed Yield

The results demonstrated seed yield per hectare that the effect of the environment on this trait has a high significant difference. Ecotype effect and environment with ecotype interaction also has a significant difference (Table 2). Mean Comparison showed that Shahmirzad and Banah ecotypes with averages of 1224kg/ha$^1$ and 470.50 kg/ha$^1$, had the highest and lowest seed yield, respectively. The mean comparison environment with ecotype interaction explained stress reduces seed yield per hectare for all ecotypes in the two environments. Mean Comparison showed that the non-stress environment, ecotypes of Sivand and Bardeskan with an average of 1800 kgha$^{-1}$ to 540 kg ha$^{-1}$ were the highest and the lowest seed yield. In environment stress, Sepidan and Qaen ecotypes, with averages of 776kg ha$^{-1}$ and 240 kg ha$^{-1}$ included the highest and lowest seed yield, respectively (Table 4). The effect of salinity can reduce plant growth and changes in photosynthetic products transported to the roots, decreasing shoot growth, especially leaves or the partial or total closure of stomata could be due to a direct effect of salt on the photosynthetic system or affect the ion balance [14]. Kafi and Keshmiri [11] showed that increasing salinity in cumin causes loss weight and reduced economic performance cumin seed in per hectare.

3.7 Dry Weight

The results illustrated the effect of the environment in ecotype and environment with ecotype interaction on this trait was highly significant (Table 2). According to comparison mean of environment and ecotype effects on this trait can be concluded that Jat and Naïen ecotypes with means of 2330.33kg ha$^{-1}$ and 2316kg ha$^{-1}$ have the highest dry weight, respectively and also Taybad with mean of 918 kg/ha had the lowest. Mean comparison about environment with ecotype interaction showed that non stress environment ecotypes such as Joopar (3412 kg ha$^{-1}$) and Bardeskan (960 kg ha$^{-1}$) were the highest and lowest dry weight, respectively. Moreover, in salty environmental Darmian ecotypes with an average of 1732 kg ha$^{-1}$ and Nehbandan with an average of 474 kg ha$^{-1}$ had the maximum and minimum dry weight, respectively (Table 4). Zidan and Elewa [6] reported that increasing salinity reduces dry weight of cumin.

Table 1. Analysis of variance based on lattice procedure

| Sources         | Sum of squares |
|-----------------|---------------|
|                 | DF | Dry weight (kg ha$^{-1}$) | Seed yield (kg ha$^{-1}$) | HI (%)   |
| Environment     | 1  | 34230963.02             | 19746140.41            | 0.44549645 |
| Block × Env.    | 2  | 71967.76$^{15}$         | 48255.14$^{16}$       | 0.00060582* |
| Variation       | 48 | 471611.21$^{17}$        | 139463.50$^{18}$      | 0.00994762* |
| Env × Var.      | 48 | 323025.82$^{19}$        | 83892.70$^{20}$       | 0.01089068* |
| Error           | 192| 737481.66               | 311785.52             | 0.01470965 |

* and ** means significant at 0.05, 0.01 and non-significant respectively
Table 2. Analysis of variance based on lattice procedure

| Sources               | DF | Plant height (cm) | Umbrel per plant | Number of seeds per umbrel | Number of seed in plant | Seed weight index(g) |
|----------------------|----|-------------------|------------------|---------------------------|------------------------|---------------------|
| Environment          | 1  | 1.632653^e        | 290.97551^ns     | 0.102041^ns              | 53148.050^ns          | 0.04816010         |
| Block × Env.         | 2  | 5.520408^ns       | 118.37551^ns     | 2.612245^ns              | 8291.866^ns           | 0.00020990^ns      |
| variation            | 48 | 111.202636^**     | 589.55833^**     | 20.984184^**             | 56347.855^**          | 0.02036264^**      |
| Env. × Var.          | 48 | 41.299320^**      | 401.24218^**     | 8.260374^**              | 41462.256^**          | 0.00774094^**      |
| Error                | 192| 39.48167          | 273.6072         | 8.310979                 | 27193.79              | 0.00718545         |

*; **and ^ns means significant at 0.05, 0.01 and non-significant respectively

Table 3. Comparison of measured traits mean in cumin populations

| Seed weight (g) | Number of seeds per plant | Number of seeds per Umbrella | Number of umbrella per plant | Steam height (cm) | Seed weight (g) | Number of seeds per umbrella | Number of seeds per plant | Number of umbrella per plant | Steam height (cm) | Ecotype |
|-----------------|---------------------------|------------------------------|------------------------------|-------------------|-----------------|-------------------------------|--------------------------|-----------------------------|-------------------|---------|
| 0.2700^e        | 416.2^i                   | 9.10^m                        | 46.70^k                      | 20.20^a           | 0.2680^m        | 151.5^cd                     | 8.70^g                    | 18.10^pg                      | 16.20^pg        | Aq-Qala |
| 0.3700^e         | 70.00^k                   | 8.50^b-l                      | 8.00^k                       | 12.80^m           | 0.2650^m        | 98.50^bcd                    | 10.40^a                   | 9.80^lg                      | 12.80^b-k       | Ardekan |
| 0.3200^e         | 65.30^l                   | 6.60^m-q                      | 9.20^k                       | 12.30^m           | 0.3050^e-m      | 84.20^pcd                    | 7.40^p                    | 109.0^a                      | 13.00^k         | Ardestan |
| 0.3400^e         | 106.4^f                   | 9.60^d                        | 10.20^j                      | 17.80^c-f         | 0.2910^l        | 128.5^a-d                    | 8.40^f                    | 14.90^b-h                     | 15.30^f         | Baf |
| 0.2580^o         | 59.30^g                   | 7.10^q                        | 7.90^k                       | 12.40^m           | 0.2630^m        | 53.60^f                       | 6.50^m-q                  | 7.30^f                        | 12.40^g         | Baneh    |
| 0.2870^q         | 91.60^d                   | 6.70^p                        | 13.80^e-k                    | 15.20^f-m         | 0.2810^g-m      | 66.60^c                       | 6.30^n-q                  | 9.80^g                        | 15.70^g         | Bardeskan |
| 0.3880^o         | 10.72^e                   | 7.60^p                        | 9.80^k                       | 14.20^m           | 0.2920^f        | 72.20^c-d                    | 8.00^n                    | 9.30^g                        | 14.70^d         | Bardsir |
| 0.3280^o         | 297.10^p                  | 8.60^b-k                      | 32.20^bc                     | 19.70^e           | 0.2550^m        | 120.2^a-d                    | 7.80^c-l                   | 15.10^b-h                     | 17.00^b-l       | Birjand |
| 0.3390^l         | 165.4^q                   | 7.90^o                        | 20.80^b-h                    | 18.00^b-t         | 0.2980^e        | 148.7^a                       | 9.10^g                    | 16.20^b-h                     | 16.10^b-t       | Bojnord |
| 0.3400^k         | 129.5^e                   | 9.00^h                        | 14.00^e-k                    | 16.50^c-f         | 0.2960^e-m      | 139.4^d                       | 8.30^m                    | 17.20^b-h                     | 18.80^abc       | Chatrood |
| 0.3020^r         | 336.2^ab                  | 9.10^m-h                      | 36.80^b                      | 20.00^e-e         | 0.2740^m        | 88.30^c-d                    | 5.50^p                    | 14.30^b-h                     | 13.30^k         | Darmian |
| 0.2910^q         | 70.90^h                   | 7.30^p                        | 9.30^k                       | 12.70^m           | 0.2790^h        | 133.0^d                      | 7.90^o                    | 17.30^b-h                     | 13.10^k         | Esfaraney |
| 0.3550^r         | 67.20^k                   | 5.80^q                        | 11.00^p-k                    | 12.40^m           | 0.3480^cos      | 60.70^c                       | 5.20^p                    | 10.80^c-n                     | 12.00^h-k       | Esthaban |
| 0.2750^q         | 76.80^e                   | 7.50^p                        | 9.90^k                       | 11.40^m           | 0.2660^km       | 57.20^d                       | 6.80^q                    | 7.40^m                        | 10.50^k         | Feridan |
| 0.3530^h         | 91.10^d                   | 8.10^o                        | 10.70^h-k                    | 13.20^m           | 0.2770^km       | 107.1^a                      | 7.50^o                    | 13.60^b-h                     | 14.70^b-f       | Ferdows |
| 0.3050^q         | 188.4^c                   | 7.40^p                        | 22.30^pet                    | 15.60^c           | 0.2930^m        | 79.60^c-d                    | 6.80^q                    | 11.30^b-h                     | 17.50^b-e       | Gonabad |
| 0.3010^r         | 77.7^i                    | 6.60^m-q                      | 11.30^p-k                    | 17.10^g           | 0.2950^em       | 151.3^d                      | 9.50^d                    | 15.70^b-h                     | 15.70^b-j       | Gonbad |
| 0.3130^o         | 87.00^d                   | 6.50^n-q                      | 12.90^x                       | 13.10^h           | 0.3270^g        | 155.9^a-d                    | 7.50^o                    | 21.20^bcd                     | 15.30^b-j       | Ivanaki |
| Seed weight (g) | Number of seeds per plant | Number of seeds per umbrella per plant | Stress environment | Number of seeds per plant | Number of seeds per umbrella | Normal environment | Ecotype |
|----------------|---------------------------|----------------------------------------|--------------------|---------------------------|----------------------------|--------------------|---------|
|                |                           |                                        | Steam height (cm)  | Seed weight (g)           | Steam height (cm)          | Number of seeds per umbrella | Number of seeds per plant | Steam height (cm) |                      |
| 0.2690bq       | 297.0                     | 9.40abc                               | 30.20cd            | 20.00ab                   | 0.3420cf                  | 178.1ab            | 8.20m               | 21.60bc          | 19.10ab           | Jat                |
| 0.2970q        | 102.7bc                   | 7.20q                                 | 30.80k             | 15.40jm                   | 0.3700em                  | 131.8ad            | 7.40o               | 16.30b           | 16.00bj           | Joopar             |
| 0.3270n        | 314.7b                    | 10.30ab                               | 29.00bcd            | 21.10abc                  | 0.2710im                  | 139.7ad            | 7.40o               | 18.60b           | 15.00cj           | Kalateh            |
| 0.4000b        | 177.5cde                  | 7.40p                                 | 20.40d             | 16.40j                     | 0.3000em                  | 106.5ad            | 6.70q              | 15.80b           | 15.90bi           | Khansar            |
| 0.3990p        | 75.20e                   | 6.70q                                 | 10.90p             | 13.30p                     | 0.2970em                  | 80.00cd            | 7.10b               | 10.17b           | 13.30k            | Khatab             |
| 0.2910q        | 59.50gr                   | 6.50q                                 | 8.50k              | 11.60mn                   | 0.2910m                   | 82.90cd            | 7.10p               | 12.70b           | 12.50g            | Kohbanan           |
| 0.3340f        | 71.20e                   | 6.90q                                 | 10.00jk            | 12.30in                   | 0.2600m                   | 80.50cd            | 7.00p               | 11.00b           | 13.10k            | Mahan              |
| 0.2860h        | 384.0bc                  | 10.00abc                              | 36.80b             | 21.70ab                   | 0.2940em                  | 108.0ad            | 9.10ag              | 11.60b           | 15.60bj           | Maraveh-Tapeh      |
| 0.3480c        | 126.9c                  | 8.30abc                              | 40.15e             | 16.20jk                   | 0.3230gj                  | 158.2ad            | 8.90az              | 17.70b           | 17.50ae           | Tapi               |
| 0.3470g        | 57.4gh                   | 6.60nmq                              | 8.30k              | 11.40mn                   | 0.4200a                   | 69.40cd            | 6.50m               | 9.40g            | 11.60k            | Naien              |
| 0.2980q        | 171.8cf                  | 9.20ag                               | 17.40l             | 16.40j                     | 0.2580im                  | 164.8abc           | 9.30ae              | 17.60b           | 15.00cj           | Natan              |
| 0.4110a        | 85.00d                   | 7.40p                                 | 10.40jk            | 14.80m                     | 0.3060em                  | 88.00cd            | 9.10g               | 11.50b           | 15.30bj           | Qaen               |
| 0.2910q        | 87.00d                   | 8.80p                                 | 9.50k              | 16.40j                     | 0.2730m                   | 100.50d            | 9.10g               | 10.90c           | 18.30ad           | Rafsanjan          |
| 0.3450f        | 110.4cf                  | 8.20n                                 | 13.40e             | 12.90n                     | 0.3030em                  | 103.00d            | 9.70bc              | 60.10b           | 13.10k            | Ravar              |
| 0.3380l        | 95.00d                   | 8.70b                                 | 10.40jk            | 0.3200m                   | 98.30cd                  | 9.00eh              | 10.60b              | 11.19k           | Sadoorea           |
| 0.3600l        | 200.0                    | 10.60a                                | 21.20g             | 20.00e                     | 0.2800hn                  | 63.40cd            | 8.50l               | 7.00             | 12.90k            | Sadoq              |
| 0.2970q        | 150.2cn                   | 6.90q                                 | 21.10g             | 16.90h                     | 0.3100em                  | 83.00cd            | 7.20p               | 11.30b           | 15.30bj           | Sarayen            |
| 0.3080p        | 170.6cf                  | 7.10q                                 | 23.50cde            | 22.80g                     | 0.3650cd                  | 119.8d             | 6.90q               | 16.70b           | 16.20bg           | Sarvestan          |
| 0.2850q        | 97.60e                   | 9.90g                                 | 9.90k              | 10.33n                     | 0.3780abc                 | 116.1cd            | 9.20t               | 11.90b           | 13.60ek           | Semirom            |
| 0.3800d        | 68.50k                   | 6.60d                                 | 10.30jk            | 11.60mn                    | 0.3990cf                  | 87.00cd            | 6.10bp              | 13.20b           | 11.90k            | Seland             |
| 0.3310m        | 76.10es                   | 7.80ro                               | 9.20k              | 12.00m                     | 0.4030ab                  | 86.60cd            | 7.50o               | 10.30eh          | 13.40k            | Shirvan            |
| 0.3260n        | 38.30j                   | 5.90q                                 | 5.70              | 10.40l                     | 0.3030em                  | 107.2d             | 6.10bp              | 17.20b           | 15.90bo           | Sirjan             |
| 0.3370l        | 82.80es                   | 8.70hk                               | 9.40k              | 11.40m                     | 0.3310cn                 | 93.50cd            | 7.90o               | 11.80b           | 14.90cj           | Sivand             |
| 0.2530l        | 51.80h                   | 7.10q                                 | 9.60k              | 12.90n                     | 0.2910m                  | 53.60              | 7.30bp              | 7.20in           | 13.10k            | Taybad             |
| 0.3830d        | 71.90eh                  | 7.40p                                 | 10.30jk            | 13.70n                     | 0.3350cg                 | 81.80cd            | 8.00on              | 9.90lh           | 15.00cj           | Torbat-Jam         |
| 0.3510p        | 90.10ds                   | 8.40jm                                | 10.30jk            | 11.40m                     | 0.3480cde                 | 103.0d             | 8.60k               | 12.20b           | 12.60k            | Torbat-Heidare      |
| 0.2810n        | 53.30bn                   | 5.40l                                 | 8.90k              | 12.60nm                    | 0.2710im                 | 206.6d             | 9.20mt              | 21.80b           | 14.30d            | Zarand             |
| 0.3850abc      | 83.60eh                   | 9.30ht                               | 8.90k              | 12.50m                     | 0.3800abc                | 121.5ad            | 9.00nh              | 13.30b           | 14.00k            | Bafq               |
| Ecotype          | Stress environment | Normal environment | Number of seeds per plant | Seed weight (g) | Number of seeds per Umbrella | Number of umbrella per plant | Steam height (cm) | Seed weight (g) | Number of seeds per umbrella | Number of umbrella per plant | Steam height (cm) |
|------------------|--------------------|--------------------|---------------------------|----------------|-----------------------------|----------------------------|-------------------|----------------|--------------------------------|-----------------------------|---------------------|
| Kashmar          | 0.3100<sup>p</sup> | 65.70<sup>**</sup> | 8.30<sup>**</sup>        | 7.70<sup>**</sup>      | 10.60<sup>**</sup> | 0.3110<sup>de</sup>        | 136.0<sup>d</sup>       | 7.80<sup>**</sup>      | 17.70<sup>de</sup>       | 15.00<sup>de</sup>       |
| Shahmirzad       | 0.2920<sup>q</sup> | 82.00<sup>**</sup> | 8.60<sup>**</sup>        | 9.10<sup>e</sup>      | 12.50<sup>**</sup> | 0.2980<sup>eem</sup>       | 144.9<sup>d</sup>       | 7.00<sup>b</sup>       | 21.80<sup>b</sup>        | 14.90<sup>b</sup>        |
| Sorkheh          | 0.2920<sup>q</sup> | 85.70<sup>d</sup>  | 7.40<sup>p</sup>        | 11.00<sup>**</sup>k   | 14.70<sup>**</sup> | 0.2980<sup>eem</sup>       | 132.0<sup>a</sup>       | 10.30<sup>ab</sup>      | 21.10<sup>be</sup>       | 20.80<sup>a</sup>        |
| Maraveh-Tapeh    | 0.2860<sup>q</sup> | 384.0<sup>ab</sup> | 10.00<sup>abc</sup>     | 36.80<sup>b</sup>     | 21.70<sup>ab</sup> | 0.2940<sup>eem</sup>       | 108.0<sup>a</sup>       | 9.10<sup>**</sup><sup>ag</sup> | 11.60<sup>b</sup>       | 15.60<sup>b</sup>        |

Table 4. Comparison of measured traits mean in cumin populations

Note: Mean follow by similar letters in each column are not significantly different
| HI %  | Stress environment | Normal environment | Ecotype |
|-------|--------------------|--------------------|---------|
| 0.5149<sup>b</sup> | 1249<sup>a</sup> | 644<sup>abc</sup> | 0.4672<sup>b</sup> | 3412<sup>a</sup> | 1596<sup>bc</sup> | Joopar |
| 0.5203<sup>c</sup> | 834<sup>a</sup>-l | 432<sup>a</sup>-d | 0.6788<sup>b</sup>-l | 1808<sup>ho</sup> | 224<sup>po</sup> | Kalateh |
| 0.4307<sup>d</sup> | 1227<sup>a</sup>-l | 528<sup>a</sup>-d | 0.6841<sup>b</sup>-l | 2180<sup>e</sup>-l | 1492<sup>abg</sup> | Khansar |
| 0.6619<sup>ab</sup> | 976<sup>a</sup>-l | 632<sup>abc</sup> | 0.4965<sup>pq</sup> | 2920<sup>b</sup>c | 1448<sup>b</sup>-l | Khatam |
| 0.5502<sup>dl</sup> | 1181<sup>b</sup>-l | 648<sup>abc</sup> | 0.7255<sup>bc</sup> | 1780<sup>ho</sup> | 1296<sup>d</sup>-l | Kohbanan |
| 0.6365<sup>ad</sup> | 916<sup>a</sup>-l | 580<sup>a</sup>-d | 0.5989<sup>op</sup> | 1616<sup>q</sup> | 968<sup>k-s</sup> | Mahan |
| 0.6713<sup>a</sup> | 632<sup>RK</sup> | 420<sup>a</sup>-d | 0.6257<sup>sn</sup> | 1608<sup>q</sup> | 1010<sup>k-s</sup> | Maraveh-Tapeh |
| 0.5460<sup>dl</sup> | 1197<sup>b</sup>-l | 508<sup>a</sup>-d | 0.6654<sup>kx</sup> | 1240<sup>pqr</sup> | 824<sup>u</sup> | Naien |
| 0.5248<sup>nh</sup> | 1701<sup>ab</sup> | 628<sup>abc</sup> | 0.6881<sup>bn</sup> | 1880<sup>g-n</sup> | 1248<sup>ho</sup> | Natanz |
| 0.4161<sup>fr</sup> | 474<sup>i</sup> | 708<sup>abc</sup> | 0.5833<sup>xo</sup> | 2932<sup>bc</sup> | 1692<sup>abc</sup> | Nahbandan |
| 0.5052<sup>kp</sup> | 5726<sup>RI-l</sup> | 240<sup>d</sup> | 0.6080<sup>op</sup> | 1375<sup>n-r</sup> | 884<sup>n</sup>-l | Rafsanjani |
| 0.4900<sup>e</sup>-q | 1057<sup>c-k</sup> | 356<sup>cd</sup> | 0.6420<sup>sl</sup> | 1549<sup>iq</sup> | 1260<sup>en</sup> | Ravar |
| 0.5151<sup>o</sup> | 1040<sup>c-k</sup> | 544<sup>a</sup>-d | 0.8085<sup>o</sup> | 1664<sup>p</sup> | 1080<sup>f</sup> | Sadroa |
| 0.5847<sup>cl</sup> | 1504<sup>a-d</sup> | 608<sup>abc</sup> | 0.6490<sup>cl</sup> | 1988<sup>fm</sup> | 1228<sup>b-p</sup> | Sadoq |
| 0.4193<sup>rh</sup> | 960<sup>bd</sup>-l | 632<sup>abc</sup> | 0.6186<sup>po</sup> | 1796<sup>ho</sup> | 1244<sup>f</sup>-f | Sarayen |
| 0.6241<sup>ae</sup> | 1144<sup>c-f</sup> | 604<sup>abc</sup> | 0.6932<sup>bg</sup> | 2092<sup>ef</sup> | 1468<sup>ah</sup> | Sepidan |
| 0.5451<sup>fl</sup> | 1572<sup>bc</sup> | 624<sup>abc</sup> | 0.6614<sup>kx</sup> | 1380<sup>n-r</sup> | 912<sup>h-t</sup> | Sarvestan |
| 0.4328<sup>gr</sup> | 1496<sup>d-g</sup> | 680<sup>abc</sup> | 0.7490<sup>o</sup> | 1212<sup>pqr</sup> | 908<sup>h-t</sup> | Semirom |
| 0.5201<sup>o</sup> | 1100<sup>b-k</sup> | 776<sup>a</sup> | 0.7025<sup>be</sup> | 2092<sup>ef</sup> | 1468<sup>ah</sup> | Sepidan |
| 0.5658<sup>kx</sup> | 1020<sup>bc-l</sup> | 616<sup>abc</sup> | 0.6995<sup>bf</sup> | 2400<sup>g-g</sup> | 1672<sup>abc</sup> | Shirvan |
| 0.6313<sup>ae</sup> | 988<sup>b-d</sup>-l | 640<sup>abc</sup> | 0.6251<sup>n</sup>-n | 2092<sup>ef</sup> | 1308<sup>b-k</sup> | Sirjan |
| 0.6550<sup>bc</sup> | 1561<sup>abc</sup> | 648<sup>abc</sup> | 0.6560<sup>cl</sup> | 2752<sup>bcd</sup> | 1800<sup>a</sup> | Sivand |
| 0.4193<sup>fr</sup> | 5563<sup>d-h</sup> | 656<sup>abc</sup> | 0.6118<sup>po</sup> | 1796<sup>ho</sup> | 1096<sup>d</sup> | Taybad |
| 0.6034<sup>nh</sup> | 1096<sup>b-k</sup> | 340<sup>cd</sup> | 0.5648<sup>mp</sup> | 2480<sup>c-f</sup> | 1376<sup>f</sup> | Torbat-Jam |
| 0.5531<sup>k</sup> | 1292<sup>f-t</sup> | 604<sup>abc</sup> | 0.6115<sup>b-o</sup> | 1832<sup>ho</sup> | 1120<sup>hq</sup> | Torbate-Heidare |
| 0.5500<sup>h</sup> | 676<sup>g-t</sup> | 680<sup>abc</sup> | 0.4295<sup>g</sup> | 3190<sup>ab</sup> | 1372<sup>g</sup>-f | Zarand |
| 0.5913<sup>cj</sup> | 712<sup>bc-l</sup> | 400<sup>bcd</sup> | 0.5935<sup>op</sup> | 1160<sup>pqr</sup> | 688<sup>flu</sup> | Bafq |
| 0.6124<sup>_g</sup> | 1360<sup>]e-e</sup> | 436<sup>a-d</sup> | 0.6241<sup>op</sup> | 1488<sup>ef-e</sup> | 928<sup>mt</sup> | Kashmar |
| 0.5640<sup>rk</sup> | 740<sup>g</sup>-i | 764<sup>ab</sup> | 0.6621<sup>kx</sup> | 2068<sup>df-l</sup> | 1368<sup>c-j</sup> | Shahmirzad |
| 0.6424<sup>abc</sup> | 740<sup>g-l</sup> | 472<sup>a-d</sup> | 0.6149<sup>op</sup> | 2237<sup>e-h</sup> | 1376<sup>c-f</sup> | Sorkheh |

Note: Mean follow by similar letters in each column are not significantly different
3.8 Harvest Index (H.I)

Analysis of variance indicated that H.I has been affected by stress. There was a highly significant difference between studied ecotypes and environment with ecotype interaction (Table 2). The mean comparison showed of Ivanki, Qaen, Sadrooa, Esfarayen, Shahmirkaz and Aq-Qala ecotypes with means of 0.66, 0.66, 0.65, 0.65, 0.65, 0.65 were the highest and Feridan ecotype with an mean of 0.49 was the lowest harvest index. Mean comparison of environment with ecotype interaction showed that stress had a significant difference on different ecotypes. The comparison between two environments showed the decreasing or increasing of this trait. The highest harvest index belonged to Ravar ecotype with an average of 0.80 and Zarand with an average of 0.42 was the lowest in stress-free environment. Also, Maraveh-Tapeh and Darman ecotypes with means of 0.67 and 0.40 were the highest and lowest harvest indexes in stressful environment (Table 4). Since this index represents the ratio economic yield (seed yield) with biological yield (dry weight). However increasing seed yield compared to increasing dry weight were not uniformly, this trait has been increasing or decreasing. Kafi and Keshmiri [11] reported that seed weight decreases with increasing salinity. Zidan and Elewa [6] stated that increasing stress could be decreasing dry weight. While Gory et al. [5] reported that salinity less than 8 ds/m is ineffective on yield components.

4. CONCLUSION

Salt stress had a significant difference on traits such as seed weight, seed yield, dry matter and harvest index. But on the other yield components such as plant height has had no significant effect. These minor changes in yield components such as plant height due to the greater impact of salinity on vegetative parts of the plant which has led to reduced cell division and vegetative growth. Ecotypes responded effect on difference to salinity was studied. That represents for genetic diversity and tolerance to stress. Ecotypes of Sepidan and Maraveh-Tapeh belong to Fars and Golestan provinces had the highest seed yield and harvest index in environment with stress. Sivand and Ravar ecotypes belong to Fars and Kerman provinces had the highest seed yield and harvest index showed in environment without stress. At least Sepidan ecotype from Fars province and Qaen ecotype from Southern-Khorasan were the most tolerance and sensitive to salinity stress.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bahraminejad AR, Mohammadi-Nejad GH, Mihdzar AKH. Genetic diversity evaluation of cumin (Cuminum cyminum L.) based on phenotypic characteristics. Australian Journal of Crop science. 2011;5(3):304-310.
2. Avatar R, Dashora SL, Sharma RK, Sharma MM. Analysis of genetic divergence in cumin (Cuminum cyminum). Indiana Journal of Genetics and Plant Breeding. 1991;51:289-291.
3. Kafi M. Cumin (Cuminum cyminum L.) production and processing, Ferdowsi University press, Iran; 2002. (In Farsi).
4. Munns R. Comparative physiology of salt and water stress. Plant, cell and Environment. 2002:25(2):239-250.
5. Gory BK, Burma Uday, Kathju S. Responses of cumin to salt stress. Indian Journal of plant physiology. 2002;7:70-74.
6. Zidan MA, Elewa MA. Effect of salinity on germination, seedling growth and some metabolic changes in four plant species (Umbelliferae). Indian Journal of Plant Physiology. 1995;38:57-61.
7. Nabizadeh Marvdast MR, Kafi M, Rashed Mohasel MH. Effect of salinity on growth, yield, elemental concentration and essential oil percent of cumin. Iranian Agricultural research. 2003;1:53-60. (In Farsi).
8. Shannon MC, Grieve CM. Tolerance of vegetable crops to salinity. Sci. Hort. 1999;78:5-38.
9. Aminpour R, Mousavi S. The Effects of number of Irrigations on development stages, yield and yield components of cumin. Journal of Science and Technology of Agriculture and Natural Resources. 1997;1(1):1-8. (In Farsi).
10. Rahimian Mashhadi H. Effect of sowing date and irrigation regime on growth and yield of Black cumin. Iranian Research Organization for Science and Technology. Khorasan Research Center. Khorasan, Iran; 1991.
11. Kafie M, Keshmiri E. Yield of landraces and cultivars in drought and salinity Hindi cumin. Jurnal of Horticultural science. 2011;25(3):327-334.

12. Armin M, Jami Moini M, Borhani N. Effect of salinity on yield and quality of Cumin (Cuminum cyminum L.). First international conference on water crisis; 2008. (In Farsi).

13. Bahraminejad AR, Mohammadi-Nejad GH, Mihdzar AKH. Molecular diversity of cumin (Cuminum cyminum L.) using RAPD markers. Australian Journal of Crop science. 2012;6(2):194-199.

14. Heidari Sharif Abadi H. Plant & salinity. Institute of forests and Rangelands Research. 2001;199. (In Farsi).

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