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EFFECT OF SALT STRESS IN DIFFERENT STAGES OF GROWTH ON QUALITATIVE AND QUANTITATIVE CHARACTERISTICS OF CUMIN (*CUMINUM CYMINUM* L.)

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ABSTRACT. Cumin (*Cuminum cyminum* L.) is one of the most important pharmaceutical plants. As a considerable portion of existing agricultural lands in arid regions is exposed to aridity and finally to salinity, we need to study the effects of salinity on the growth and production of agronomical products. For this purpose, an agricultural experiment in the form of split plots with three replications was conducted in 2011 at the Islamic Azad University, Gonabad Branch, Iran, in the longitude of 58°, 50', latitude of 34°, 54', and altitude of 940 m from the sea level. At the main plot, four salinity levels (2,5,8 and 11ds/m) and at the sub plot, the growth stages of stress implementation (including stress in establishment, flowering, and seed filling stage), were located at random. The results showed that the salinity rate had significant impact on fresh weight, dry weight, height , percentage of essence, seed and biological yield. With the increase in salinity from 2 to 11ds/m, a significant decrease in all vegetative and reproductive characteristics were observed. The most sensitive growth stages of plant to salt stress, during vegetative and reproductive period were the stage of establishment and flowering, respectively. There was no interaction between the growth stage of plant and salinity rate, except for seed yield and harvest index.

Key words: Salinity stress; Growth stage; *Cuminum cyminum* L.

INTRODUCTION

Soil salinity is among environmental tensional factors that make problem for plants in terms of nutrition and metabolic processes further to disordering and decreasing water absorption by roots (Alebrahim *et al.,* 2004). This factor is one of the most important problems in agricultural and natural areas and effects plant and finally the total ecosystem. Cumin is among pharmaceutical plant in agronomical classification of plants. It contains 7% tannin, 13% oil, and 2.5 to 4% resin

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and essence (Zargary, 2001). Either in tissue culture and cultivation of cumin, researches have shown that germination of plant will decrease with the increase of salinity. Salami and Safarnejad (2005), in their research on the resistance of different genotypes of cumin against salinity in the germination stage, reported that these genotypes had shown a high resistance rate to this tension; and Sarayan cultivar had higher resistance to salinity in comparison with cultivars of Torbat Jam and Mashhad. Nabizadeh *et al.* (2004) having added NaCl and $CaCl_2$ to the sandy soil of cumin concluded that salinity had a negative impact on production of cumin. Tatari and Abbasi (2004), having effected different levels of salinity and using different periods of irrigation, studied the growth and production of cumin in Mashhad, and concluded that all growth and biologic indices of cumin decrease with the increase of salinity rate. Ghamarnia *et al.* (2012) have studied the effect of saline irrigation water on black cumin (*Nigella sativa*) and reported that with increase in salinity from 2 to 6 ds/m, grain yield and oil yield significantly decreased. Davazdah Emami and Mazaheri (2009) reported that the percentage of essence of seed and vegetative parts of Ajowan (*Carum copticum)* will significantly decrease with the increase in the rate of salinity.

MATERIAL AND METHODS

Experiment was conducted at the Islamic Azad University, Gonabad Branch, Iran, in the longitude of 58°, 50', latitude of 34°, 54', and altitude of 940 m from the sea level in 2011 in the form of split plots with three replications, in the main plot, salinity factor including, EC= 2 ds/m, EC= 5 ds/m, EC= 8 ds/m, EC= 11 ds/m and in the sub plot, growth stages of stress implementation including: time of establishment, flowering time, seed filling time, were put on random.

Seeds of native cultivar "Ferdows City" were planted in December 2011, at the rate of 15 kg/ha with 60 cm row space in depth of 0.5 cm.

In each stage of growth, plots were being irrigated with waters of different EC. Meanwhile, the result of soil analysis of the location of experiment showed that salinity of soil standing at 1.79 ds/m.

The following were measured and calculated: percentage of essence with distillation method, number of seeds in each plant, number of seeds in umbrella, number of umbrellas in plant, weight of one thousand seeds, seed yield, height of plant, and biologic yield.

We used SAS software (9.2 versions) for analysis of data and Excel for drawing charts and graphs, mean comparison was done on %5 probability level via Duncan's test.

RESULTS AND DISCUSION

Effect of salinity treatment

The general trend of results of this research in connection with plant production showed that (*Table 1*) it is severely under the impact of salinity rate; in such an extent that on the level of 11 ds/m we faced with the lowest production (*Table 2*).

This decrease in production was the result of decrease in number of seeds in plant and weight of one thousand seeds; and the most significant difference was seen in number of seeds in plant. This decline was accelerated in soils with EC of higher than 5 ds/m, and the highest decrease was seen in the treatment of 11 ds/m. It is probably for a disorder in photosynthesis, resulting in a negative effect on the seed production organs. The results approve the result of examination conducted by Tatari *and* Abbasi (2004) on cumin. Garg *et al.* (2002) reported that Salinity levels at and above 8 dS m^{-1} significantly reduced seed yield, nutrient uptake and levels of most of the leaf metabolites such as total chlorophyll, starch and soluble protein. Nitrate reductase activity, however, was most sensitive to salt stress.

Also with the increase in salinity from 5 to 8 ds/m (*Table 2*) we saw a significant decrease in weight of seeds. It seems that a change in photosynthesis path for the sake of presence of salt in ambient environment of the root and in plant tissues will lead to a decrease in dry weight of seeds; may be because some processed materials are used for adjusting the effects of salinity tension (Huang and Redmann, 1995). These results correspond with the results achieved by Nabizadeh *et al.* (2004), Tawfik and Noga (2001) and Davazdah Emami and Mazaheri (2009) about cumin.

Also with the increase in salinity rate, wet weight, dry weight and seed production (*Table 2*) will have significant difference in all four treatments. It seems the main reason for decrease in seed production is significant decrease in number of seeds in plant. The maximum seed production with the average of 264.72 relates to the irrigation with the water of EC= 2 ds/m and the minimum one (208) relates to the irrigation treatment with the water of EC = 11 ds/m; and with the increase in salinity from 2 to 11 ds/m, seed production rate decreases about 55%. The results corresponds with the results achieved by Tatari and Abbasi *(*2004), Nabizadeh *et al.(*2004) on cumin and Reggiani *et al.*(1995) on wheat.

The results showed that biologic yield will decrease with the increase in salinity in such an extent that biologic yield will decrease about 72% while salinity increases from 2 to 11 ds/m. It seems the main reason of biologic yield decrease is the reduction of height of plant.

According to *Table 2* the harvest index will increase by increase of salinity rate; showing a significant difference with other salinity rates. The reason is that biologic yield is more under effect of salinity than economic aspects.

In regard to harvest index that is an estimation of effective conversion of dry matter to seed production, the results of experiments are very different; so that François *et al.* (1994) stated that under salinity stress production of chaff and stubble of rye *(Secale cereale*) is more sensitive than seed yield in this plant; so salinity results in increase of harvest index of this plant.

Table 1 - Analysis of variance of the effect of salinity rate and growth stage and their interaction on the measured characteristics (Mean square)

Source of variation	Degree of freedom	Wet weight	Dry weight	Number of seeds in plant	Number of seeds in umbrella	Number of umbrellas in plant	Percentage of essence	Weight of one thousand seeds	Height of plant	Seed yield	Biological yield	Harvest index
Block	2	659.4*	164.9 ns	3241 ns	26.2*	8.69 ns	1.42 ns	0.34 ns	9.13*	172 ns	1050 ns	29.5 ns
Salinity A	3	11080**	5270**	55957**	74.5*	185.5**	819.2**	2.54**	195**	463246**	1978534**	832.5**
Error (a)	6	401.3	138	1965	13.46	10.6	16.3	0.21	4.42 ns	1114	874	29.2 ns
Growth Stage (B)	2	1746**	830.5**	12845*	34.2*	4.36 ns	53.1 ns	1.35**	28.2**	5812**	95010**	743.7*
Salinity* growth stage	6	46.1 ns	21.9 ns	1102 ns	1.49 ns	3 ns	14.47 ns	0.09 ns	0.96 ns	9911**	1770 ns	201.4**
Error (b)	16	39.2	82.18	25.82	7.91	8.51	19.93	0.13	5.6	2115	3329	30.5

**: significant on the level of 1%; *: significant on the level of 5%; Ns: non-significant

Table 2 - The effect of salinity treatment on the measured characteristics

Salinity treatment	Wet weight (g)	Dry weight (g)	Number of umbrellas	Seeds in umbrella	Seeds in plant	Essence percentage (%)	Weight of one thousand seeds (g)	Height of plant	Biologic yield	Harvest index	Seed yield
2 ds/m	193.17A+	133.22A	20.22A	11.22A	227.87A	2.72A	4.01A	19.24A	1426.00A	32.77C	464.72A
5 ds/m	178.59B	123.17B	19.00A	11.23A	215.09A	2.55B	3.69A	17.14B	1116.00B	40.51B	450.63B
8 ds/m	149.05C	102.79C	13.66B	10.74A	139.85B	2.41C	3.11B	11.84C	625.10C	42.41B	260.00C
11 ds/m	113.80D	78.48D	10.55B	5.32B	57.02C	2.14D	2.84B	9.160D	389.33D	55.90A	208.00D

The averages in each column with the same letters have no significant difference with each other on 5% level of Duncan test.

Table 3 - The effect of growth stage on the measured characteristics

Growth stage	Wet weight (g)	Dry weight (g)	Number of umbrellas	Seeds in umbrella	Seeds in plant	Essence percentage (%)	Weight of one thousand seeds (g)	Height of plant	Biologic production	Seed production	Production index
Establishment	145.67B+	100.46B	16.25A	11.13A	191.15A	2.51A	3.72A	12.81C	980.22A	358.80A	51.90A
Flowering	160.76A	110.87A	15.16A	7.80B	125.91B	2.45A	3.06B	14.36B	802.43C	328.61B	39.47B
Seed filling stage	169.52DA	116.91A	16.18A	9.94A	162.81A	2.41A	3.46A	15.87A	884.81B	350.29A	37.32B

The averages in each column with the same letters have no significant difference with each other on 5% level of Duncan test.

But Kafi and Stewart (1998) and Zheng and Shannon (2000) have reported, respectively, the decrease in harvest index of wheat and rice with the increase in salinity more than threshold of the plant; they reason that this is because of a more decrease in seed production in comparison to chaff production in salinity treatments. In saline soils, lesser photosynthetic matter will be allocated to seed, resulting in a decrease in harvest index.

The experiment showed that height of plan will decrease with the increase in salinity i.e. the height of cumin plant and salinity of water has reversal relation with each other (*Table 2*). Nabizadeh *et al.* (2004) in their exam on cumin saw and reported such relation. The decrease of growth in plants under salinity tension is for the reason of decrease in energy reserves of the plant, which itself it because of a decrease and disorder in metabolic and biologic activities of plant. In fact, the effect of ions and disorders in photosynthesis process directly effect on production of biomass of plant.

The general trend of results of this research concerning the rate of the produced essence showed that (*Table 2*) the percentage of essence is severely under the effect of the ambient salinity rate; so that this amount is maximum with an average of 2.72 when salinity rate is equal to 2 ds/m; that shows a significant difference with other salinity rates. Meanwhile, the minimum percentage of essence production, standing at 2.14%, relates to the highest salinity rate. The results achieved tally with the results of researches conducted by Ashraf and Foolad (2007), Zidan and Elewa (1994) and by Davazdah Emami and Mazaher (2009) on Ajotva plant (*Carum copticum).*

Effect of growth stage treatment on the measured characteristics

Results of this research apparently showed that establishment stage is the most sensitive stage to salinity treatments in cumin for the vegetative characteristics including dry weight, wet weight, and height of plan (*Table 3*). In fact, at this stage, irrigation with salty water has resulted in the minimum amounts of wet weight and dry weight at the establishment stage. In regard to these cases (wet and dry weights), the establishment stage shows a significant difference with other stages. Botella *et al.* (1993), in a similar research on wheat, concluded that the vegetative characteristics of plant such as weight will be more affected when it is under severe salinity at the initial stage of growth in comparison with when it is treated with such stress at the next stages.

The characteristics relating to the reproductive stages such as number of seeds in umbrella, number of seed in plant, seed weight, biologic production, and seed production, show the maximum decrease with salinity treatment at the flowering stage (*Table 3*). Such conclusion tallies with the conclusion of Tatari and Abbasi (2004) and Nabizadeh *et* *al.* (2004). However, salinity had no significant effect on the "number of umbrellas" and "percentage of essence". In the light of the fact that umbrellas will be produced before flowering stage, we can conclude that this fact is the reason for lacking significant effect on "number of umbrellas" at the flowering stage and seed filling stage while the plant is under treatment of salinity. Meanwhile, such characteristics as "number of seeds in umbrella" or "number of seed in plant" will decrease at the maximum level because they are determined at the flowering stage. Of course, considering the fact that at seed filling stage the maximum transfer of photosynthetic materials occurs, we should expect a decrease in seed weight at this stage, but it seems that salinity has more effect on number of seeds than on transfer of photosynthetic materials; and such conclusion corresponds to the conclusion of Shalhevet *et al.* (1995) in corn.

Interactive effects of salty water irrigation treatment and growth stage of plant

According to the results of this research, there is no interaction between salinity treatment and growth stage on the characteristics of plant except for seed yield and harvest index (*Table 1*), whereas they have effects on the said characteristics separately. In this regard, there is no significant difference between the said characteristics in different stage of life of cumin plant and in different salinity rate. These results correspond to the conclusion of Nakhzari Moghaddam (2010), relating to the research on cumin in which the correlative effects of water treatment and cultivation density had no significant meaning.

According to the results, it was revealed that seed production in cumin significantly decreases with the increase in salinity of irrigation water. Seed production rate of cumin stands at an average of 464.72 kg/ha when it is irrigated with 2 ds/m salty water; and it significantly decreases to 208 kg/ha when salinity increased to 11 ds/m. This decrease in production rate should be regarded to the decrease in seed production rate and number of seeds produced by plant, finally leading to a decrease in this characteristic. The results attest conclusion of Nabizadeh *et al.* (2004) at their research on cumin plant.

According to *Table 4*, it was revealed that in correlation with salinity the most sensitive stage of cumin's life in terms of seed yield is flowering stage. This stage shows a significant difference with two other stages (establishment and seed fillings). As indicated, this factor is under effect of two other factors of "weight of one thousand seeds" and "number of the produced seed in plant". These two factors decreased in the flowering stage.

Table 4 - Effect of salinity and growth stage of plant and their interaction on seed yield in cumin plant

Salinity/growth stage	Establishment	Flowering	Seed filling	Effect of salinity rate
2 ds/m	468.42a+	458.54a	467.30a	464.72A
5 ds/m	433.62b	448.58ab	469.66a	450.63B
8 ds/m	280.11c	240.87d	259.21cd	260.00C
11 ds/m	253.00d	166.56f	204.63e	208.00D
Effect of growth stage	358.80A	328.61B	350.29A	

The averages with the same letters (small letters relate to interaction and capital letters relate to means) have no significant difference with each other on 5% level of Duncan's test.

Table 5 - Effect of salinity and growth stage of plant and their interaction on harvest index in cumin plant

Salinity/growth stage	Establishment	Flowering	Seed filling	Effect of salinity rate
2 ds/m	36.01def	31.85ef	30.46f	32.77C
5 ds/m	42.33cd	40.05cd	39.13cde	40.51B
8 ds/m	50.87b	39.67def	36.70def	42.41B
11 ds/m	78.39a	46.33bc	42.97cd	55.90A
Effect of growth stage	51.90A	39.47B	37.32B	

The averages with the same letters (small letters relate to interaction and capital letters relate to averages) have no significant difference with each other on 5% level of Duncan test.

According to *Table 5,* we can inference that the most harvest index may be achieved when the plant is faced with salinity stress at the establishment stage. It is may be for the minimum effect on seed production rate in comparison with two other stages. Also this index at this stage has significant difference with other stages. Ranjbar (2010) has reported that the effect of salt stress on harvest index was different among wheat cultivar.

CONCLUSIONS

These results demonstrated that cumin (*Cuminum cyminum* L.) is a sensitive medicinal plant to salinity and its tolerance significantly differs in different stages of growth. According to this study, maximum salinity tolerance for economically cumin yield is 5 ds/m and the most sensitive stage of growth to salt stress in the vegetative and reproductive stages are establishment and the flowering stage, respectively.

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