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Original article

Evaluation of chitosan application on growth characteristics, biochemical and essential oil content of summer savory under different soil moisture levels

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Extended abstract

Introduction

Environmental stresses play an important role in the pattern of plant distribution worldwide, and drought stress in turn determines a large part of this distribution. Drought stress is the most important environmental factor limiting the growth and development of plants in the world so that the growth reduction due to drought stress is much greater than other environmental stresses. One of the ways to reduce drought stress damage in plants is the use of biopolymers and chitosan is one of these compounds. Chitosan has become one of the leading biopolymers for plants against various stresses in recent decades due to its numerous properties. Due to the side effects of chemical drugs, the use and importance of medicinal plants are increasing. Savory is one of the most widely used and widely used medicinal plants. Savory (*Satureja hortensis* L.) is an annual or perennial herbaceous plant, fragrant and belongs to the Lamiaceae family. The aim of this study was to investigate the effect of chitosan foliar application on growth, biochemical properties, and amount of savory (*Satureja hortensis* L.) essential oil under different levels of soil moisture.

Materials and Methods

This study was conducted in the research greenhouses of the Ferdowsi University of Mashhad in 2019-2020 as a factorial in a completely randomized design with 2 factors and 3 replications. The first factor was different levels of soil moisture (30, 60, and 90% of field capacity) and the second factor was different levels of chitosan foliar application (water control, acetic acid control, 0.5, 1, and 2 g l^{-1}). Different levels of soil moisture were applied when the plants reached the 4-6 leaf stage. Before applying drought stress, soil arable capacity was determined. Chitosan foliar application was performed in two stages. The first stage was when the plants were in the 6-8 leaf stage and the second foliar application was done two weeks after the first foliar application. During the growing season, all crops, including weed control, were uniformly applied between treatments. The studied traits included growth characteristics, wet and dry biomass of shoots and roots, relative leaf water content, electrolyte leakage, proline content, malondialdehyde, hydrogen peroxide, and essential oil.

Results and discussed

Based on the obtained results, with decreasing soil moisture, growth indices and relative water content of plant leave decreased significantly, and in contrast, leakage of electrolytes, proline, malondialdehyde,

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hydrogen peroxide, and plant essential oil was increased. The highest amount of hydrogen peroxide (0.24 mg g^{-1} fresh leaf weight) was observed at the lowest soil moisture level (30% of field capacity) and the use of chitosan, especially at the level of 0.5 g l^{-1}, reduced the significance. The application of this concentration of chitosan reduced the leakage of electrolytes and hydrogen peroxide by 8.86% and 23.77% at the highest stress levels, respectively. Also, the application of 0.5 g l^{-1} of chitosan caused that at the highest level of stress, plant height, shoot and root biomass, and relative leaf water content Increase 2.78, 60.18, 118.18, and 18.6 (percent), respectively. However, application of 2 g l^{-1} of chitosan intensified the stress in the plant so that the amount of electrolyte leakage at the lowest soil moisture level (30% of field capacity) and application of 2 g l^{-1} of chitosan compared to the control (no use of chitosan) with 11.98%. The increase was accompanied. Also, the highest amount of proline (0.0194 µg g^{-1}) was observed in the application of 2 g l^{-1} of chitosan and 30% of soil capacity.

Conclusion

Chitosan foliar application, especially the application of 0.5 g l^{-1}, improved the growth characteristics, the relative leaf water content of the plant and also reduced the damaging effects of electrolyte leakage, malondialdehyde, and hydrogen peroxide in savory. In general, the results of this study showed that the use of chitosan improved the tolerance of savory under drought stress.

***Keywords*:** Biomass, height, Hydrogen peroxide, Malondialdehyde, Proline

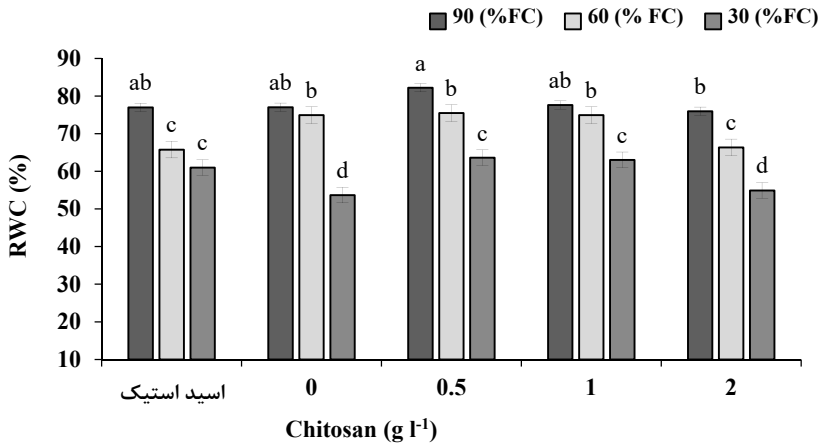

Fig. 1. Interaction of different levels of soil moisture and chitosan on the relative water content of *Satureja hortensis* leaves

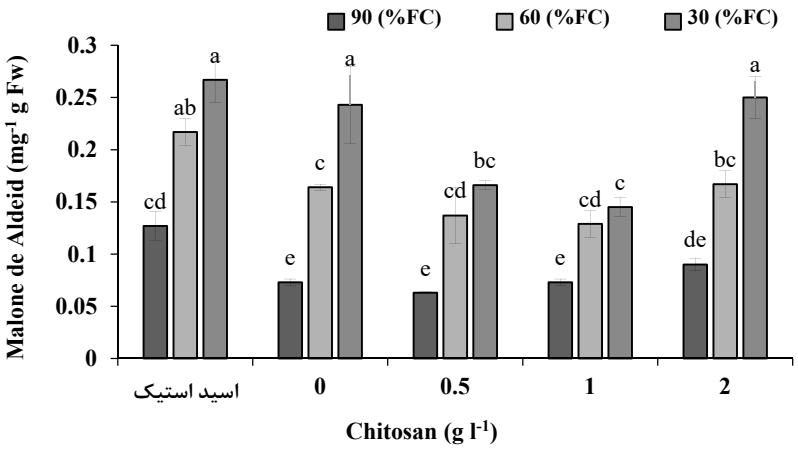

Fig. 2. Interaction of different levels of soil moisture and chitosan on malondialdehyde content of *Satureja hortensis*

Table 1. Analysis of variance the effect of chitosan foliar application on growth traits of Satureja hortensis under different levels of soil moisture

S.O.V	df	Plant height	Number of brunches	Stem diameter	Leaf length	Leaf width	Number of node
Soil moisture (a)	2	78.11**	115.10**	0.51**	72.61**	3.17**	4.17**
Chitosan (b)	4	23.94**	28.59**	0.18**	2.26**	0.74**	0.94**
(a)×(b)	8	15.35**	10.99**	0.24**	37.38**	0.44**	1.88**
Error	30	2.08	0.50	0.02	0.41	0.02	0.23

Table 1. Continued

S.O.V	df	Internode length	Fresh weight of aerial part	Dry weight of aerial parts	Root fresh weight	Root dry weight
Soil moisture (a)	2	0.77**	14.35**	3.335**	0.420**	0.0003**
Chitosan(b)	4	0.17**	0.46**	0.120**	0.422**	0.0157**
a × b	8	0.51**	2.03**	0.102**	0.003 **	0.0020**
Error	30	0.02	0.06	0.007	0.0003	0.000061

**Significant at 1% probability level.

Table 2. Analysis of variance the effect of chitosan foliar application on biochemical properties and essential oil content of *Satureja hortensis* under different levels of soil moisture

S.O.V	df	RWC	Electrolyte leakage	Proline	MDA	H_2O_2	Essential oil content
Soil moisture (a)	2	477.77**	22.40**	0.000073**	0.01779**	0.012**	1.52**
Chitosan (b)	4	112.55**	12.82**	0.000041**	0.0126**	0.020**	0.36**
a × b	8	237.81**	18.81**	0.000074**	0.0123**	0.005**	0.39**
Error	30	3.00	2.25	0.000001	0.00026	0.0001	0.03

** Significant at 1% probability level.

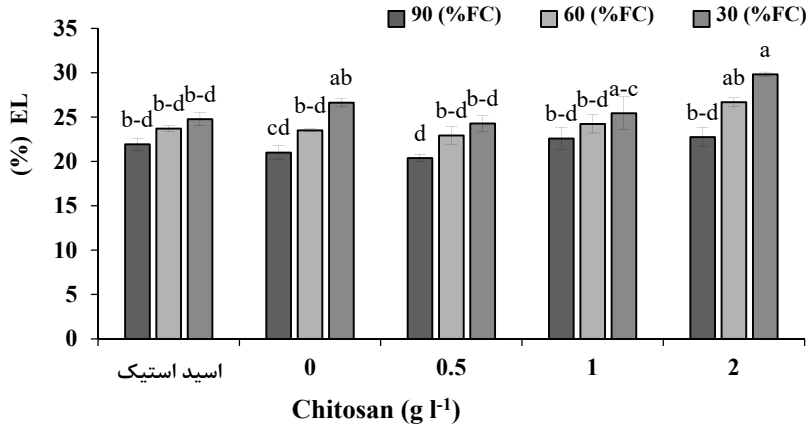

Fig. 3. Interaction of different levels of soil moisture and chitosan application on electrolyte leakage of *Satureja hortensis*

Table 3. Mean comparison of the effect of chitosan foliar application on growth traits and essential oil content of *Satureja hortensis* under different levels of soil moisture

Soil moisture	Chitosan	Plant height	Number of brunches	Stem diameter	Leaf length	Leaf width	Number of node
FC%	g l^{-1}	cm		----------mm----------			
90	**Acetic acid**	43.7±0.96^{a-d}	16.8±0.43^{cd}	1.98±0.01^{a-c}	24.0±0.57^{cd}	3.1±0.06^{bc}	12.5±0.289^{a-d}
90	**0**	44.9±0.01^{a-c}	18.3±0.43^{bc}	2.30±0.11^{a}	25.2±0.27^{bc}	4.2±0.06^{a}	13.0±0.033^{ab}
90	**0.5**	47.2±0.086^{a}	23.1±0.63^{a}	2.31±0.09^{a}	31.1±0.41^{a}	4.2±0.05^{a}	13.5±0.289^{a}
90	**1**	45.4±1.400^{a}	20.3±0.43^{b}	2.22±0.03^{ab}	26.7±0.21^{b}	3.5±0.09^{b}	13.0±0.289^{ab}
90	**2**	43.5±0.76^{a-d}	17.3±0.66^{cd}	1.75±0.08^{cd}	23.1±0.34^{d}	3.1±0.07cd	12.0±0.289a^{-d}
60	**Acetic acid**	42.4±0.90^{b-d}	16.2±0.16^{cd}	1.75±0.07^{cd}	22.6±0.47^{de}	2.8±0.08^{c-e}	11.3±0.144^{cd}
60	**0**	40.6±0.61^{c-e}	15.5±0.29^{f-f}	1.74±0.07^{cd}	22.6±0.09^{de}	2.7±0.03^{c-e}	11.7±0.333^{b-d}
60	**0.5**	43.5±0.95^{a-d}	16.5±0.29^{cd}	1.88±0.14^{a-d}	23.4±0.16^{cd}	3.1±0.03^{cd}	13.3±0.333^{a}
60	**1**	42.4±0.94^{b-d}	16.5±0.29^{cd}	1.81±0.05^{b-d}	22.7±0.77^{de}	2.8±0.02^{c-e}	12.4±0.220^{a-d}
60	**2**	42.1±0.23^{b-d}	15.8±0.14de	1.70±0.13^{c-e}	22.5±0.44de	2.7±0.11^{c-e}	11.5±0.289^{b-d}
30	**Acetic acid**	36.8±1.607^{e}	11.8±0.43^{gh}	1.53±0.02^{c-e}	20.5±0.47^{fg}	2.6±0.01^{e}	11.0±0.289^{d}
30	**0**	39.5±0.144^{de}	13.3±0.44^{e}	1.46±0.07^{c-e}	19.1±0.10^{g}	2.6±0.16^{e}	11.7±0.333^{b-d}
30	**0.5**	40.6±0.61^{c-e}	13.8±0.44^{e-g}	1.70±0.06^{c-e}	21.0±0.02^{e-g}	2.7±0.03^{c-e}	12.7±0.333^{a-c}
30	**1**	40.3±0.49^{c-e}	12.8±0.14^{gh}	1.65±0.02^{c-e}	20.6±0.10^{e-g}	2.6±0.002^{de}	12.3±0.333^{a-d}
30	**2**	36.8±0.349^{e}	10.8±0.44^{h}	1.29±0.07^{e}	17.1±0.08^{h}	2.4±0.15^{e}	11.2±0.167^{cd}

Table 3. Continued

Soil moisture	Chitosan	Internode length	Fresh weight of aerial part	Dry weight of aerial parts	Root fresh weight	Root dry weight	Essential oil content
FC%	g l^{-1}	cm	----------g/plant----------				%v/w
90	**Acetic acid**	3.2±0.005^{a-c}	5.10±0.26^{bc}	1.67±0.01^{ab}	0.21±0.016^{cd}	0.09±0.0050^{d}	2.2±0.0403^{b-d}
90	**0**	3.3±0.0023^{ab}	5.36±0.04^{ab}	1.86±0.07^{a}	0.24±0.0096^{bc}	0.11±0.0023^{bc}	1.7±0.0274^{d}
90	**0.5**	3.6±0.0033^{a}	6.37±0.21^{a}	1.76±0.16^{a}	0.32±0.0152^{a}	0.19±0.0033a	2.5±0.0115^{a-c}
90	**1**	3.3±0.0124^{ab}	4.52±0.03^{b-d}	1.76±0.06^{a}	0.28±0.0093^{ab}	0.17±0.0124^{a}	2.0±0.023^{cd}
90	**2**	3.1±0.004^{b-d}	4.15±0.47^{c-e}	1.57±0.06^{a-c}	0.12±0.0089^{ef}	0.07±0.004^{d-g}	2.3±0.1300^{bc}
60	**Acetic acid**	2.8±0.003^{c-e}	3.73±0.08^{d-f}	0.84±0.01^{ef}	0.10±0.0086^{f}	0.06±0.0034^{fg}	2.5±0.0515^{a-c}
60	**0**	3.0±0.002^{b-e}	2.62±0.03^{g-i}	1.08±0.07^{de}	0.11±0.0066^{f}	0.06±0.003^{e-g}	3.0±0.193^{a}
60	**0.5**	3.3±0.0029^{ab}	4.27±009^{c-e}	1.30±0.07^{b-d}	0.28±0.0038^{ab}	0.12±0.0029^{b}	3.0±0.161^{a}
60	**1**	3.2±0.002^{a-c}	3.71±0.01^{d-f}	1.28±0.06^{cd}	0.17±0.0104^{de}	0.08±0.0017^{de}	2.3±0.017^{bc}
60	**2**	2.6±0.0051^{ef}	2.63±0.09^{g-i}	0.85±0.04^{ef}	0.10±0.0026^{f}	0.05±0.0051^{fg}	2.3±0.156^{bc}
30	**Acetic acid**	2.3±0.0001^{f}	3.08±0.11^{f-h}	0.66±0.02^{f}	0.09±0.0005^{f}	0.05±0.0001^{g}	2.6±0.0378^{ab}
30	**0**	2.6±0.003^{d-f}	2.16±0.05^{hi}	0.81±0.05^{ef}	0.11±0.0105^{f}	0.06±0.0028^{fg}	2.8±0.225^{a}
30	**0.5**	3.3±0.0007^{a-c}	3.46±0.02^{e-g}	1.15±0.09de	0.24±0.0096^{bc}	0.09±0.0007^{cd}	3.0±0.025^{a}
30	**1**	3.1±0.0006^{bc}	3.26±0.34^{e-g}	0.87±0.01^{ef}	0.13±0.0089^{ef}	0.07±0.0006^{d-f}	3.0±0.0491^{ab}
30	**2**	2.3±0.049^{f}	2.05±0.06^{i}	0.67±0.03^{f}	0.10±0.0077^{f}	0.05±0.049^{fg}	3.1±0.049^{a}

Similar letters in each column shows non-significant difference according to Bonferroni test at 5% level

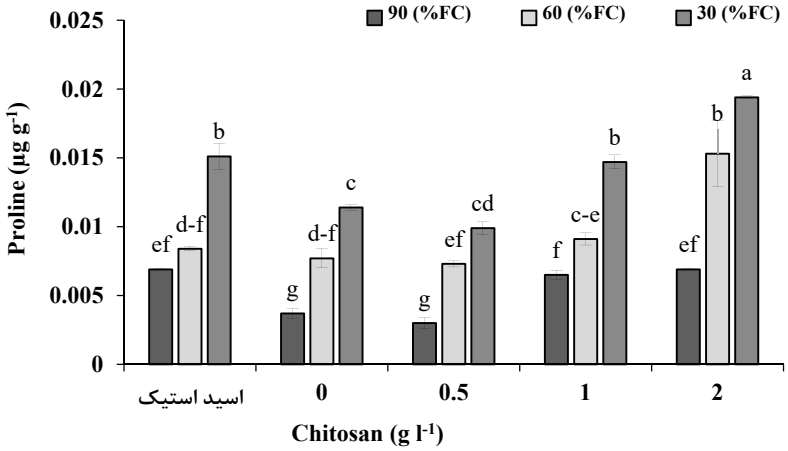

Fig. 4. Interaction of different levels of soil moisture and chitosan application on proline content of *Satureja hortensis*

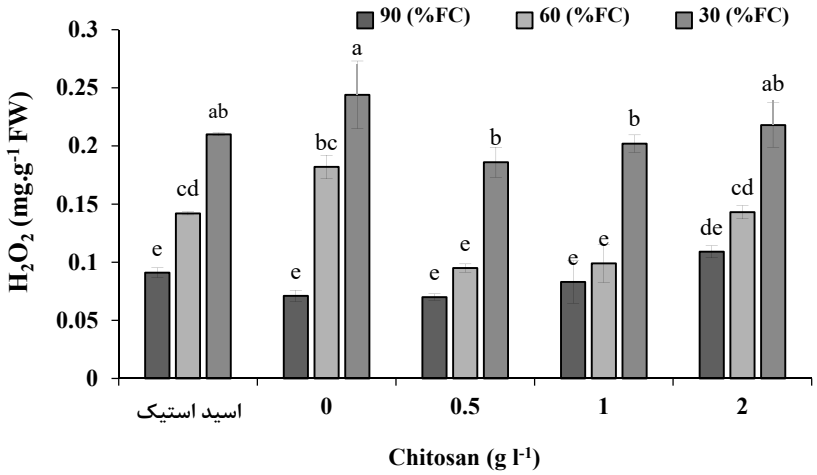

Fig. 5. Interaction of different levels of soil moisture and chitosan application on the amount of hydrogen peroxide of Satureja hortensis