International Journal of Horticultural Science and Technology (2024) Vol. 11, No. 2, pp. 175-188

International Journal of Horticultural Science and Technology
Journal homepage: http://ijhst.ut.ac.ir

Interactions of Organic Fertilizers and Planting Densities on Essential Oil and Plant Yield of *Satureja mutica* in Dry Farming

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ARTICLE INFO

Article history:

Received: 27 February 2023,
Received in revised form: 28 August 2023,
Accepted: 4 September 2023

Article type:

Research paper

Keywords:

Dry farming,
Essential oil,
Savory,
Yield

ABSTRACT

White savory is a medicinal plant native to Iran. It is known for its tolerance to water-deficit conditions. A farm experiment evaluated cultivation in dryland conditions while describing interactions among organic fertilizers (O. F.). Planting densities affected essential oil (EO) and yield-related traits in white savory under dryland farming. This experiment was conducted in the Mehregan Research Station, Kermanshah, by a split-plot design based on RCBD with three replications, and three fertilizer treatments, i.e., cow manure (30 tons ha^{-1}), wheat straw enriched with sulfate ammonium (10 tons ha^{-1}), and farm soil. There were three planting densities, i.e., low-density (2.66), medium-density (4), and high-density (8 plant m^{-2}) during the 2017-2018 and 2018-2019 crop years. The highest two-year average of fresh yield (3149.90 kg ha^{-1}) and dry yield (1611.70 kg ha^{-1}) occurred in response to rotten cow manure × high-density treatment. The highest two-year average of EO percentage (2.19%) resulted from using rotten cow manure × low-density planting. The highest EO yield (32.60 kg ha^{-1}) resulted from enriched straw × high-density planting. The highest plant fresh yield (3434.02 kg×ha^{-1}), plant dry yield (1231.98 kg ha^{-1}), and EO yield (24.68 kg ha^{-1}) resulted from the second year of harvest. We recommend dry farming *S. mutica* in a modified substrate using 30 tons ha^{-1} rotten cow manure and a row spacing of 50 × 25 cm in mountainous regions, where annual rainfall is more than 450 mm on average.

Abbreviations: Essential oil (EO), Enriched straw (ES), Farm soil (FS), High density (HD), Low density (LD), Medium density (MD), Organic fertilizer (O. F.), Rotten cow manure (RMC)

Introduction

Cultivating economically valuable plants with low water requirements in dryland conditions is a way to protect water resources. One such economic plant is the white savory (*Satureja mutica* Fisch. & C. A.). It is resistant to drought stress and shows a low water requirement, making it a proper candidate for cultivation in dryland farming as a medicinal plant (Karimi et al., 2022).

The genus *Satureja* L. is from the Lamiaceae family and has more than 200 species, mainly distributed in the Mediterranean region (Rechinger, 1980). Eight of these species,

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including *S. mutica*, are endemic to mountainous areas in Iran (Jamzad, 2012; Mozaffarian, 1996). The white savory is a perennial, relatively woody plant species. It is 45 cm in average height, with tall flowering stems and short hairs on the leaves (Jamzad, 2012).

White savory is a medicinal plant with antispasmodic, sedative, and anti-infective properties. It has uses in traditional medicine for treating rheumatic pain, migraine, toothache, and diarrhea. It is used as a food additive (Mazandarani and Monfaredi, 2017) and in the health industry (Gohari et al., 2011). Phenolic constituents of *S. mutica*, such as thymol and carvacrol, have antioxidant and antimicrobial activities against several pathogens that affect humans (Mazandarani and Monfaredi, 2017; Sadeghi et al., 2013; Adiguzel et al., 2007).

While obtaining higher yields in the field requires access to sufficient nutritional elements for the plant, the long-term application of chemical fertilizers can lead to environmental pollution and soil degradation (Chandini et al., 2019; Nasir Khan et al., 2017). Organic fertilizers (O. Fs.) contain plant- or animal-based materials such as animal manure and composted organic materials (Hitha et al., 2021). These organic fertilizers can improve plant production and uphold environmental conservation (Askary et al., 2018; Degueurce et al., 2016; Sun et al., 2015). Through organic fertilizers and the mineralization process, nitrogen converts to its absorbable forms and gradually enhances leaf chlorophyll synthesis (Khan et al., 2008). This conversion increases the uptake of trace elements, such as Fe, Zn, and Cu (Rahimi et al., 2019) and subsequently increases morphological traits and biological yield (Rahimi et al., 2019; Alami-Milani et al., 2015).

Also, the organic matter content in dryland soils defines the soil's ability to increase rainwater infiltration and maintain soil moisture (Walsh and Mc Donnell, 2012; Mamnabi et al., 2020). Therefore, organic fertilizers can indirectly increase water availability (Adiaha, 2017).

Inter-plant competitions aim to optimize environmental growth factors and cause plants to decrease yield and economic value (Villalobos et al., 2017). Planting density can directly affect the absorption of sunlight, water, and nutrients (Wu et al., 2016; De-Yang et al., 2016). Therefore, tight-row spacing (tighter than optimal) increases plant competition. It results in limited accessibility to the required resources (Jiang et al., 2013; Ciampitti and Vyn, 2011; Rossini et al., 2011) and induces abiotic stress in plants (Osakabe et al., 2014). Based on a model by Deng et al. (2012b), biomass production per area would increase linearly by an increase in plant density up to an optimal planting density. Densities higher than optimal would decrease the production level.

The main goal of the present study was to investigate the effects of different organic fertilizers and plant densities in dryland farming on the production and yield of white savory.

Material and Methods

Field experiments

This research happened in two consecutive cropping years, 2017-2018 and 2018-2019, in Mehregan Research Station, Kermanshah Agricultural and Natural Resources Research and Education Center. The experimental field station was at 34°.9= latitude, 47°.9= longitude, and at 1270 m altitude.

We used three levels of organic fertilizers, i.e., rotten cow manure (30 tons ha^{-1}), hay enriched with ammonium sulfate (10 tons ha^{-1}) (two kg of ammonium sulfate per 100 kg of hay), and the control treatment without fertilizer. These treatments were the main factors of a split-plot design. Three plant densities were, i.e., low density (LD) (2.66 plants per m^2) with 50 × 75 cm row spacing, moderate plant density (MD) (4 plants per m^2) with 50 × 50 cm row spacing, and high plant density (HD) (8 plants per m^2) with 50 × 25 cm row spacing. These treatments were considered the sub-plot. Therefore, the overall number of plots equaled 27 (3 fertilizer × 3 plant densities × 3 replication). Since the experimental design appeared as a split-plot, each main plot measured 36 m2 in area and was split into three sub-plots, each measuring 12 m^2 (3 × 4 m^2). We did not use any herbicides or pesticides during the project. Weed control was mechanical.

Land preparation and fertilizer treatment application

In autumn, the field was plowed and leveled. The treatments were applied before sowing the seeds and in early autumn. Thirty-six kg of rotten cow manure constituted one treatment group. Twelve Kg of wheat straw, enriched with 240 g of ammonium sulfate (dissolved in 20 liters of water), made another treatment group. These fertilizers were evenly distributed on the furrows in each subplot and subsequently covered with farm soil.

We analyzed the field soil samples and fertilizer treatments in the soil and water laboratory of the Kermanshah Agricultural and Natural Resources Research Center. In the laboratory, the soil samples were dried, pounded, and passed through a two mm sieve. Chemical analysis was done according to standard methods. The percentage of soil constituents was measured by a hydrometric method, and the type of soil texture was determined (Klute and Dirksen, 1986). The electrical conductivity and soil pH acidity were measured (Corwin and Yemoto, 1996). The soil electrical conductivity (ds m^{-1}) was determined by a WTW EC meter, LF 197, Germany, in standard conditions at 25 °C. Soil acidity (pH) was measured by Hanna's pH meter, HI 2211, USA. Soil mineral elements were measured using a plasma device, ICP700, OES Agilent Technologies, USA. The soil organic matter was measured by the Walkley–Black method. The results of analyzing the fertilizer treatments and the farm soil are presented in Table 1. Furthermore, Table 2 shows the meteorological conditions of the experimental field as a semi-arid steppe climate class. Table 3 presents the monthly precipitation in the station.

Table 1. Physical and chemical characteristics of fertilizer treatments and the control.

Fertilizer treatment	Soil Texture	EC (ds m^{-1})	pH	Absorbable P (ppm)	Absorbable K (ppm)	O.C. (%)
Farm soil (without fertilizer)	Silty-Clay	0.70	7.03	12.20	520	1.13
Enriched wheat straw	-	-	-	26	860	22.03
Rotten cow manure	-	-	-	138	6800	1.75

Seed planting and seedling preparation

After obtaining the seeds from the Forests and Rangelands Research Institute of Iran, we disinfected them with 5% sodium hypochlorite for 2 min and dried them. To produce seedlings, we planted the seeds in trays and peat moss in a greenhouse at 18-24 °C and with 35% humidity (Firoozeh et al., 2019). White savory seedlings were adequately transferred to the field and planted on March 11, 2017.

Morphological traits

Plant survival was the percentage of established plants. Various morphologic traits, including plant height and crown diameter, were measured. We cut the plants from 5 cm of the soil surface in October, weighed them, and recorded the average fresh weight (Saeidinia et al., 2019). The average dry weight of each plant appeared after drying the plant samples in an oven for 72 hours at 70 °C (Bian and Jiang, 2008). Then, we calculated the fresh yield (kg ha-1) and dry yield (kg ha-1) by multiplying the average plant fresh weight or average plant dry weight × plant count per ha (Yousefi et al., 2023).

Essential oil

Plant samples were collected to measure the essential oil (EO) content. The harvest was in late August (flowering stage). After harvesting the plants, we dried, weighed, and crushed them. The EO was extracted using seventy grams of plant powder by water distillation and involved the Clevenger system, according to British Pharmacopoeia (1993).

Table 2. Metrological statistics in the Kermanshah weather station during the two crop years.

Crop years	Absolute maximum temperature (˚C)	Absolute minimum temperature (˚C)	Average of maximum temperature (˚C)	Average of minimum temperature (˚C)	Average of annual temperature (˚C)	Average of humidity (%)	Average of annual evaporation (mm)	Annual precipitation (mm)	Long term rainfall (mm)
2016-2017	40.8	8.2	24.8	7.7	16.6	37	1931	394.5	470.7
2017-2018	43.5	10.6	23.6	8.3	16.74	45	162.6	434	470.7

Table 3. Monthly rainfall distribution during the growing season and annual rainfall statistics (mm) in the Kermanshah weather station during the two crop years.

Crop years	October	November	December	April	May	June	July	August	September	Year's rainfall
2016-2017	0	1	14.7	132.5	22.1	0	0	0	0	394.5
2017-2018	0	33.8	10.2	63.4	169	5.2	0	0	0	434

The Clevenger apparatus operated for three hours. The essential oil samples were separated into 5 ml vials. They were dehydrated with dry sodium sulfate (Na_2SO_4) and stored in a refrigerator (4 °C). Subsequently, the EO percentage (weight/weight or W/W method) was calculated by the following formula (Shahin et al., 2021): %EO = EO weight (g) / plant dry weight (g) ×100

The EO yield was calculated based on the plant dry weight and the herbal extract weight using the following equation:

EO yield (kg ha^{-1}) was obtained by multiplying the EO (%) by dry plant weight per hectare.

Statistical analysis

This experiment was performed as a split plot on a randomized complete block design (RCBD), in which three organic fertilizers were the main factor and three planting densities as the sub-factor. There were three replications (blocks). SPSS (ver. 26) enabled a homogeneity test of variance (Levine's Test) between the two years, combined analysis of variance, and comparison of mean values (p=0.05) by Duncan's test and Pearson's correlation coefficient (Yousefi et al., 2023).

Results

ANOVA and mean comparison

The analysis of variance (Table 4) showed significant differences between the two years. The differences were evident in plant height, canopy diameter, plant fresh weight, plant dry weight, fresh yield, dry yield, essential oil yield per hectare ($P \leq 0.01$), and plant survival (%) ($P \leq 0.05$). Also, there were significant differences among fertilizer treatments by their effects on canopy diameter, plant fresh weight, plant dry weight, fresh yield, dry yield, EO yield ($P \leq 0.01$), and plant survival (%) ($P \leq 0.05$). Also, significant differences occurred among plant density treatments, affecting plant survival, canopy diameter, plant fresh weight, plant dry weight, fresh yield, dry yield, and EO yield ($P \leq 0.01$).

Mean comparisons of interaction effects between fertilizers and planting densities (Table 5) showed that the highest plant survival (%) resulted from the application of enriched wheat straw × low planting density (66.15%). The lowest plant survival percentage was observed in the rotten cow manure × high planting density treatment (40.63%). Maximum plant height (35.56 cm) occurred in response to rotten cow manure × high-density. Minimum height (25.04 cm) was observed in farm soil (control) × moderate planting density. Rotten cow manure × low planting density resulted in the highest crown diameter (34.38 cm), whereas the smallest crown diameter occurred in response to enriched wheat straw × high planting density treatment. Treating plants with rotten cow manure × low planting density caused them to achieve the highest plant fresh weight (55.46 g); however, applying no fertilizer × high planting density caused the lowest fresh weight (26.13 g). The application of rotten cow manure × low planting density maximized the plant's dry weight (28.15 g), whereas no fertilizer (control) × high planting density minimized it (11.75g). Applying rotten cow manure under high planting density effectively maximized the fresh yield (3149.90 kg ha^{-1}) and dry yield (469.41 kg ha^{-1}), whereas having no fertilizers under low planting density resulted in minimal fresh yield (982.21 kg ha^{-1}) and dry yield (469.41 kg ha^{-1}). The highest EO percentage (2.19%) and EO yield (32.60 kg ha^{-1}) resulted from the effects of rotten cow manure × low planting density and enriched wheat straw × high planting density, respectively. Rotten cow manure with medium planting density led to the lowest EO percentage (1.79%), and no fertilizer application under low planting density resulted in the lowest EO yield (9.81 kg ha^{-1}). The highest plant fresh yield (3434.02 kg ha^{-1}), plant dry yield (1231.98 kg ha^{-1}), and EO yield (24.68 kg ha^{-1}) appeared in the second year of cultivation.

Pearson's correlation

Pearson's correlation estimation (Table 6) showed that plant survival correlated significantly with plant fresh weight (r=0.62), plant dry weight (r=0.64), and plant crown diameter (r=0.56). Similarly, plant height correlated significantly with plant crown diameter (r=0.72), plant fresh weight (r=0.43), and plant dry weight (r=0.47). Significant positive correlations occurred between plant crown diameter and plant dry weight (r=0.76), plant fresh weight (r=0.74), plant dry yield (r=0.37), and plant fresh yield (r=0.34). Correlations between fresh weight and plant dry weight (r=0.96), fresh yield (0.29), and dry yield (0.31) were positively significant. In addition, plant dry weight positively correlated with the fresh yield (r=0.32) and dry yield (r=0.39). A significant positive correlation (r=0.98) occurred between plant fresh yield and dry yield. EO percentage showed no significant correlation with any of the measured traits in white savory plants, although the EO yield correlated significantly with all measured characteristics, except for the EO percentage and plant survival (%) (Table 6).

Table 4. Results of combined variance analysis (mean squares) for morphologic and yield traits in *S. mutica* plants cultivated under dry farming.

Source of variations	df	Plant survival	Plant height	Plant crown	Plant wet weight	Plant dry weight	Fresh (wet) yield	Dry yield	EO percent	EO yield
Year (Y)	1	3855.0^{ns}	1531.0**	2152.0**	5036.0**	1674.0**	10900000**	3474000.0**	0.07^{ns}	1501.0**
Block/Y	4	327.91	29.00	29.87	12.66	8.36	31650.0	23410.0	0.04	5.09
Fertilizer (F)	2	289.43*	271.11^{ns}	212.4**	1580.0 **	437.21**	3281000.0**	995300.0**	0.02^{ns}	374.48**
Y×F	2	65.35^{ns}	107.18^{ns}	55.42 *	172.59^{ns}	38.54*	490600.0**	86720.0*	0.13*	52.42**
Block/Y×F	12	58.21	63.62	9.76	18.04	5.04	38330.0	11910.0	0.03	5.53
Density (D)	2	1568.0**	0.86^{ns}	84.12**	1056.0**	241.59**	9977000**	2498000.0**	0.05^{ns}	904.63**
Y×D	2	117.97^{ns}	112.9 **	14.35^{ns}	32.52*	26.76**	709600.0**	187200.0**	0.15*	53.03**
F×D	4	73.87^{ns}	25.75^{ns}	22.04^{ns}	19.58*	4.48^{ns}	157900.0**	98410.0**	0.13*	51.53**
Y×F×D	4	169.03^{ns}	22.0^{ns}	22.89^{ns}	20.91*	5.73^{ns}	108600.0**	13010.0^{ns}	0.15*	11.18^{ns}
Error	20	1.42	13.48	8.84	5.40	3.74	1.73	9.23	0.04	6.59
CV (%)		2.15	11.87	10.22	5.34	9.04	6.63	0.31	10.08	13.23

* and ** = significant difference at 5% and 1%, respectively, and ns=no significant difference.

Table 5. Comparison of mean values in morphological and yield traits of *S. mutica* plants cultivated under dry farming,*.

Treatments	Mean ± SD				
	Plant survival (%)	Plant height (cm)	Plant crown diameter (cm)	Plant wet weight (g)	Plant dry weight (g)
Y1	47.07±11.23a	25.60 ±5.83b	22.79±4.68b	33.84±10.80b	15.83±4.32b
Y2	63.97±15.48a	36.25±7.74a	35.41±9.79a	53.15±8.25a	26.96±4.81a
RCM×HD	40.63±11.79b	35.56±9.28a	31.70±7.74abc	39.37±11.81c	20.15±6.84c
RCM×MD	61.11±15.74a	35.09±6.15a	33.09±9.41ab	52.66±10.77ab	24.91±7.10b
RCM×LD	63.54±20.03a	32.98±11.89ab	34.38±10.93a	55.46±13.70a	28.15±10.40a
ES×HD	52.26±6.02ab	29.19±4.28abc	22.56±6.73f	39.06±5.03c	19.91±4.06c
ES×MD	60.76±17.15a	33.28±3.55ab	27.99±9.27cde	50.81±5.97b	25.31±4.28b
ES×LD	66.15±14.85a	31.80±5.85ab	30.50±5.39bcd	56.04±10.62a	27.02±7.08ab
FS×HD	42.71±11.60b	28.11±7.15bc	25.58±8.35ef	26.13±11.82e	11.75±5.23d
FS×MD	52.08±9.77ab	25.04±9.70c	29.09±6.23cde	35.08±15.59d	17.77±6.46c
FS×LD	60.42±21.16a	27.33±11.23bc	26.94±4.67de	36.83±13.08cd	17.60±6.23c

Mean values with the same letter are not significantly different (Duncan's test; p=0.05), *: Mean comparison between 2 years is based on analysis variance. ES: enriched straw, FS: farm soil, HD: high density, LD: low density, MD: medium density, O. F.: organic fertilizer, RMC: rotten cow manure.

0

Table 5. (continue).

Treatments	Mean ± SD			
	Wet yield (kg×ha^{-1})	**Dry yield (kg ha^{-1})**	**EO percent (%)**	**EO yield (kg ha^{-1})**
Y1	1535.53±443b	724.70±231b	1.95±0.14a	14.14±4.65b
Y2	2434.02±618a	1231.98±314a	2.02±0.18a	24.68±5.54a
RCM×HD	3149.90±944.89a	1611.70±547.11a	1.91±0.14bc	30.34±8.93a
RCM×MD	2106.50±430.62b	996.60±283.80b	1.79±0.17c	18.19±6.63b
RCM×LD	1479.00±365.24c	750.72±277.38c	2.19±0.40a	17.34±9.02b
ES×HD	3124.60±402.69a	1592.40±324.99a	2.04±0.17abc	32.60±7.74a
ES×MD	2032.50±238.90b	1012.30±171.35b	2.02±0.20abc	20.36±3.62b
ES×LD	1494.40±283.14c	720.61±188.75c	1.87±0.12bc	13.43±3.42c
FS×HD	2090.60±945.96b	940.39±418.26b	2.01±0.13abc	18.90±8.54b
FS×MD	1403.20±623.65c	710.89±258.55c	1.99±0.43abc	13.73±4.30c
FS×LD	982.21±348.90d	469.41±166.20d	2.07±0.10ab	9.81±3.83d

Mean values with the same letter are not significantly different (Duncan's test; p=0.05). ES: enriched straw, FS: farm soil, HD: high density, LD: low density, MD: medium density, O. F.: organic fertilizer, RMC: rotten cow manure.

Table 6. Pearson's correlation estimation between morphologic and yield traits in *S. mutica* plants cultivated under dry farming.

Traits	Plant survival	Plant height	Plant crown	Plant wet weight	Plant dry weight	Wet yield	Dry yield	EO percent	EO yield
Plant survival	1								
Plant height	0.30*	1							
Plant crown	0.56**	0.72**	1						
Plant wet weight	0.62**	0.43**	0.74**	1					
Plant dry weight	0.64**	0.47**	0.76**	0.96**	1				
Wet yield	-0.04	0.33*	0.34*	0.29*	0.32*	1			
Dry yield	0.01	0.35*	0.37**	0.31*	0.39**	0.98**	1		
EO percent	0.16	0.18	0.15	0.04	0.15	-0.08	-0.03	1	
EO yield	0.07	0.37**	0.39**	0.33*	0.42**	0.94**	0.97**	0.20	1

* and ** indicate significance levels at 5% and 1%, respectively.

Discussion

In the current research, plant spacing affected all morphological and yield-related traits except plant height and EO percentage. Organic fertilizer treatments significantly improved plant height and crown diameter, plant fresh weight, dry weight, fresh yield, and dry yield. Accordingly, the highest amounts of the mentioned traits occurred in response to rotten cow manure. Similarly, enriched wheat hay significantly increased the EO yield, but the highest EO percentage occurred in response to using farm soil (the control). In some reports, similar to our results, cow manure led to a significant increase in morphological and yield traits in *S. mutica* (Asadollahi et al., 2022), *S. spicigera* (Bahreininejad et al., 2022), and *Satureja bachtiarica* (Mirjalili et al., 2022).

As mentioned earlier, organic fertilizers did not affect the EO percentage of S. mutica. Similarly, Akrami Nejad et al. (2016) reported that organic fertilizers did not affect EO percentage in S. hortensis plants. On the contrary, Esmaielpour et al. (2018) reported that cow manure application significantly increased the EO percentage in summer savory. Organic fertilizers reportedly had significant effects on EO content and EO yield in various medicinal plants (Keshavarz et al., 2019; Giovannini Costa et al., 2013; Anwar et al., 2005).

The current study showed the highest fresh yield (3149.90 kg ha^{-1}) and dry yield (1611.70 kg ha^{-1}) in the interaction effect of rotten cow manure × high-density planting (row spacing 50 × 25 cm). The highest EO yield (32.60 kg ha^{-1}) occurred by applying enriched wheat straw × row spacing of 50 × 25 cm. Similar to our results, Saki et al. (2019) reported that in *S. mutica* plants under irrigation conditions, cattle manure and high planting densities (row spacing of 50 × 25 cm) led to higher plant production. In *Satureja bachtiarica* plants, under irrigation conditions, the highest EO yield was observed in plants supplied with manure (30 tons ha^{-1}) and a row spacing of 50 × 25 cm (Mirjalili et al., 2022). In S. mutica cultivation under irrigated conditions, the highest flowering shoot yield (4266 kg ha^{-1}) and the highest EO yield (79.27 kg ha^{-1}) were obtained by using N50P25K25 + cow manure 60 tons ha^{-1} (Asadollahi et al., 2022), thereby confirming the results of the current study. According to previous research by Bahreininejad et al. (2022) on dry farming *S. spicigera* plants, the highest fresh yield (2844 kg ha^{-1}) and dry yield (1433kg ha^{-1}) occurred by using farm soil (compared to cow manure × row spacing of 50× 25 cm).

One of the reasons behind the positive effects of organic fertilizers on the yield traits of *S. mutica* in the current study was the availability of essential and required nutrients, such as potassium and phosphorus (according to soil analysis). Bakr (2016) reported that using manure increased the availability of N, P, and K in the soil, leading to soil fertility and subsequently increased plant yield. Also, in water-deficit conditions, manure can improve root development (Tahami et al., 2017) and provide an appropriate environment for the activity of bacterial populations, thereby complementing the effects of chemical fertilizers (Scheffer et al., 2013). Competition among plants often results in power-law relations between crowding measures, such as plant density, average size, and individual biomass (Friedman, 2016). These indicate how plant biomass increases by decreasing the planting density (Assaad et al., 2020). Depending on the plant species, plant genetics (Pant and Sah, 2020; Deng et al., 2012a; Guo et al., 2011), environmental (Ilkaee et al., 2017), and nutritional conditions (Mook and van Der Toorn, 2022; Pant and Sah, 2020; Zhang and Tielbörger, 2020), the response of plants to planting density might be diverse. Thus, different and sometimes contradictory reports exist on the effects of planting densities on the same or other plant species.

Conclusion

We recommend dry farming of white savory in the west and north of Iran, especially in temperate mountainous regions with more than 450 mm precipitation. Under dry farming conditions, to achieve high fresh and dry yield, we recommend plantations with rotten cow manure (30 tons ha^{-1}) and 8 plants/m^2 (50×25 cm) to obtain the highest EO yield. We recommended using enriched hay with ammonium sulfate (12 tons ha^{-1}) and 50×25 cm row spacing.

Funding

This research was supported by the Research Institute of Forest and Rangelands (RIFR) of Iran.

Conflict of Interest

The authors indicate no conflict of interest in this work.

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