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Influence of different weed management techniques on the growth and essential oils of dragonhead (*Dracocephalum moldavica* L.)

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Abstract

Moldavian dragonhead (Dracocephalum moldavica L.) is an annual herbaceous plant from Lamiaceae family and is known to be native to the temperate climate of Asia. It is recognized that balm-scented leaves of dragonhead have some medical influences. Weeds are one of the most important problems in medicinal plant production and may cause a significant loss in both plant yield and their active ingredients. We evaluated the effects of different weed control techniques on the growth, content and composition of essential oils of dragonhead in northwest of Iran. weed control treatments was including No weeding (weedy check); one hand weeding at 20 DAS; two hand weeding at 20 and 40 DAS; weed free (regular hand weeding at 10 days interval until harvest); Treflan herbicide (pre-emergence control); Gallant Super herbicide (post emergence control) and soil solarization (use of clear polyethylene). Growth parameters, herbage yield and content of essential oil were significantly influenced by different weed control treatments. Result showed that the maximum biological yield and essential oil content were obtained from weed free condition followed by two hand weeding and soil solarization. Essential oil analyses indicated that neral, geraniol, geranial, and geranyl acetate were the most abundant compounds. The lowest amount of neral was recorded in plants grown under chemical weed control. Overall finding of current experiments suggested that eco-friendly approaches, mainly soil solarization and regular manual weeding might be the best option to combat weed problems as well as to obtain satisfactory herbage yield and an acceptable quality of essential oil content in dragonhead. This finding has important implications for developing non-chemical weed control in medicinal plants.

Keywords: *essential oil, herbage yield, herbicides, solarization, weed control*

1. Introduction

Moldavian dragonhead (*Dracocephalum moldavica* L.), also known as dragonhead or Moldavian balm, is an annual, herbaceous, balm-scented and spicy aromatic plant belonging to the Lamiaceae family (ABDOSSI & al. [1]; YOUSEFZADEH & al. [2]). Dragonhead is native to central Asia and it has become naturalized in many locales in eastern and central Europe (POVILAITYEE and VENSKUTONIS [3]). This plant is generally utilized as a food-related ingredient and extracts of the plant have a large quantity of pharmacological actions such as tranquilizing, analgesic, and appetite-stimulating, with stimulation of the activity of the digestive organs (POPOVA & al. [4]). Furthermore in northwest of Iran, distilled aqueous extracts from *D. moldavica* are used as a beverage (DMITRUK and WERYSZKO-CHMIELEWSKA [5]). The most cultivation area of Moldavian balm in Iran is related to north and northwestern parts, particularly in the western regions of Azerbaijan province, and in the Albourz Mountains (DASTMALCHI & al. [6]). Although this plant can be grown on wide range of soils and climatic conditions, active chemical constituents can be significantly affected by environmental condition or agronomic management practices (YOUSEFZADEH & al. [2]; JANMOHAMMADI & al. [7]).

The fundamental objective in cultivation of medicinal plants is to obtain the maximum active ingredients and secondary metabolites. However, cultivation of medicinal plants faced a number of limitations and constraints such as nutritional imbalance, water shortage, and lack of appropriate genotypes, climatic condition and weed infestation (UPADHYAY & al. [8]. In the main, suitable agronomic managements can be resulted in production of vigorous, fast-growing medicinal plants which will provide the best competition against weeds. Although some limitations associated with cultivation of medicinal plants partially have been investigated, little work has been carried out on the weed control methods in the fields of medicinal plants. Weeds are one the most important problems in agriculture and cause a significant loss in medicinal plant yield and this can be due to their early emergency, high densities, ability to grow in limited soil moisture. It seems that in semi-arid regions competition between weeds and medicinal plants is primarily for moisture and nutrients and often leads to reducing the survival and growth of young medicinal plants (PRAKASA & al. [9]; MATKOVIĆ & al. [10]). Besides, uncontrolled weeds can provide safe harbour for insects and diseases, also produce seed or rootstocks which infest the field and affect future crops. Therefore to achieve potential yield and acceptable quality of medicinal plants is required weeds population to be minimized below the economic threshold level through the suitable weeds management techniques. It is clear that diminishing the weed population below threshold level, reduce competition for growth and development, and supply appropriate situation to improve the quantity and quality of the medicinal plants (MATKOVIĆ & al. [10]).

Weed management systems falls into different categories and more prominent are chemical weed control, soil solarization and mechanical weed control. However weed management in medicinal plants seems to be more complicated compared to other crops and the question is often asked whether the application of herbicides can be put into practice. Although chemical weed control is especially an efficient option for reducing weed population, it must always be considered that both medicinal plants and weeds absorb the chemical compound in different amounts. Consequently, chemical weed control may positively or negatively impact the metabolic processes. Although, chemical weed control suggests a benefit to save labor and money, as a result, considered as cost effective (AHMED & al. [11]), these methods may have some unpleasant side effects e.g. herbicide may sprayed onto nearby medicinal plants and can be absorbed by them, some herbicides can persist in the soil for long time and it may negatively affect the future vegetation growth, herbicides can be ingested as residual substances and some of the herbicides can create weed resistance. On the contrary, non-chemical weed control has become an attractive topic in recent years as it seems that chemical herbicides may have some undesirable side effects on the growth and qualitative aspects of medicinal plants (UPADHYAY & al. [8]). Among these methods, soil solarization is an eco-friendly technique for weed control using high temperatures produced by capturing radiant energy from the sun (KHALID & al. [12]), in spite of this fact application of this technique has not been well studied in medicinal plants. Overall, it may be stated in all fairness that our information about weed control effects on growth and chemical constituents of medicinal species is poor and we know still less about the response of Moldavian dragonhead to different weed management techniques. Nevertheless, commercial cultivation of medicinal plants demands strong and continues attention to effect of such managements practices on both herbage yield and quality of essential oil. The objectives of this experiment were to evaluate the effects of different weed management approaches on morpho-physiological traits and essential oil content of Moldavian dragonhead under semiarid condition.

2. Materials and Methods

A field experiment was conducted at Agronomy research field, University of Maragheh, Iran, during the period of April-August 2014. The field was located at 37° 24' N, 46° 16' E and an altitude of 1485 meter from sea level. The area is one of the best representatives of highland semi-arid zone. According to the updated classification of Köppen and Geiger, climate of Maragheh is categorized as BSk; cold semi-arid climate. Average annual precipitation of Maragheh is 353 mm, consisting of 73% rain and 27% snow. The average annual rainfall during the dragonhead growing season was 76 mm, of which more than 95% was received from March to May. Average maximum and minimum temperature during growing season was 34 °C and 8.7 °C, respectively.

Despite utilizing a diversified management system, medicinal plants growers still have weed problems. The target of this research was to evaluate the impact that different management practices on the growth and internal chemical composition of Moldavian dragonhead. The weed management practices included T_1: no weeding (control); T_2: one hand weeding at 20 days after sowing (DAS); T_3: two hand weeding at 20 and 40 DAS; T_4: weed free (regular hand weeding at 10 days interval until harvest to maintain weed-free fields); T_5: Treflan herbicide (pre-emergence control, 2.5 L ha^{-1}); T_6: Gallant Super herbicide (post emergence control, 1L ha^{-1}); T_7: soil solarization (use of clear polyethylene).

Treflan (EC 48%; Trifluralin) was mixed with water (100 lit ha^{-1}) and was soil incorporated whit in 4 hours after utilization. Treflan is selective pre-emergence herbicide for control of many annual grasses and broadleaf weeds by disrupting growth process during germination. Gallant Super (EC 10.8%; haloxyfop-R-methyl) applied as systemic post emergence control at 30 DAS by foliar spraying. Herbicide was diluted with water (at 100L ha^{-1} rate), and sprayed over the foliage to point of run-off (until every leaf was completely wetted, but not dripping). Soil solarization occurred in moist soil when covered by transparent plastic film, was sealed into the soil around its edges and heated by exposure to sunlight from 30 days before the sowing. Transparent plastic film permit short-wave radiation from the sun to penetrate the plastic. The field was kept under constant observation from sowing till harvesting. The most prevailing weeds recorded at fields during experiment were *Portulaca oleracea*, *Chenopodium album*, *Amaranthus retroflexus*, *Lactuca serriola*, *xanthium strumarium*, *Convolvulus arvensis*, *Cynodon dactylon, Alopecurus myosuroides*, *Sisymbrium irio*, *Alhagi maurorum*, *.cuscuta* sp. (Dodder) and *Centaurea depressa*.

The experimental fields were ploughed two times in early fall and 30 days before planting by using moldboard, subsequently soil harrowed twice to bring the soil to fine tilth. The experiment was carried out in randomize complete block design with three replications and a net plot size was as 6 × 5 m. Seeds of *Dracocephalum moldavica* (Bonab landrace) were obtained from the West Azerbaijan Agriculture and Natural Resource Research Center. Seeds were hand sown on 21 April, 2014, row spacing was 30 and intra row spacing was 10 cm. There was no incidence of pest or disease on dragonhead during the experiment. All other agronomic practices were kept normal and uniform in the treatments. The crop was harvested on July 27 (at 50% flowering). After harvesting some of morphological traits such as plant fresh weight, dry weight of inflorescences, leaf number, number of lateral branches, number of flowering branches, number of flowers per plant, length of flower organ in main stem, height of the first flowering branch, plant heights, lateral stem number, stem diameter and fresh and dry weight of leaves were measured in ten plants from the middle of the plots. Chlorophyll index was measured on fully expanded leaves from ten plants per plot, using a portable chlorophyll meter (SPAD) at early flowering stage. Fresh and dry weight plants were measured with digital weighing scales. The average canopy spread was measured from north to south (one side of canopy to the other side).Dragonhead plants were cut at ground level and were air-dried at 28 °C for 10 days under shadow. Oil extraction was performed by using a Clevenger apparatus (YOUSEFZADEH al. [2]). The distillations were carried out on sample size of 100g of dried material (aerial parts), with a distillation time of 150 min (30 min after the last additional oil volume change). The extraction of oils was carried out according to method that introduced by the European Pharmacopoeia [13]. The oils were dried over anhydrous sodium sulphate and stored in sealed vials at 2 °C before analysis.

Oil samples were analyzed by gas chromatography (GC) with mass spectrum (MS). Gas chromatography–mass spectroscopy (GC–MS) were carried out using a Varian 3400 GC–MS system equipped with a DB-5 fused silica column (30 m × 0.25 mm i.d., film thickness 0.25 µm). The injection volume was 1.0 mL and the injector temperature was 260 °C, and the linear velocity of the helium carrier gas was maintained at 31.5 cm s^{-1}, with a split ratio of 1:60, an ionization energy of 70 eV, a scan time of 1 s, and a mass range of 40–300 amu. Component identification was made based on matching retention times and MS of unknown components with the identified standards. Statistical analyses were performed using Statistical Analysis Systems (SAS 9.1) software. Differences were analyzed by ANOVA. Means were compared by the LSD test ($p < 0.05$).

3. Results

Results of variance analysis showed that the effect of weed control treatments on dragonhead fresh weight, plant biomass, dry weight of inflorescences, number of leaves, number of lateral branches, number of flowering branches, number of flowers per plant was statistically significant (Table 1). The lowest fresh weight of dragonhead plants was recorded under no weeding condition, while the highest fresh weight was obtained from solarized soil (T_7) and weed-free conditions (T_4). These treatments could improve the fresh weight of dragonhead plants up to three times compared to no weeding condition (T_1). On the other hand chemical controls (T_5 and T_6) had negligible improving effects on fresh weight (Table 1). The relatively similar trend was recorded for plant biomass, so that the highest biomass was obtained from plants grown under weed free conditions (T_4). Mean comparison of inflorescences fresh weight revealed that the highest value was obtained from dragonhead plants grown under weed free condition and those received two times weeding (T_3), respectively. The same trend also was observed for dry weight of inflorescences. However, the other treatments were not significantly different from each other. Assessment of inflorescences dry weight showed that the lowest value was related to no weeding and Treflan application (T_5) condition (Table 1).

Table 1. Morphological traits of Moldavian dragonhead (*Dracocephalum moldavica* L.), as affected by weed control treatments.

Weed control treaetments	PFW	PDW	IFW	IDW	PH	NL	NLB	NFB	NFP
No weeding	12.85^{c}	3.21^{d}	2.92^{b}	0.51^{c}	74.78^{a}	103.56^{d}	1.67^{d}	1.78^{bc}	19.55^{b}
1 hand weeding	17.71^{bc}	4.71^{dc}	3.20^{b}	0.75^{bc}	79.45^{a}	117.33^{cd}	2.78^{cd}	2.45^{bc}	26.00^{b}
2 hand weeding	30.26^{ab}	7.20^{b}	5.64^{ab}	1.29^{ab}	83.22^{a}	203.89^{b}	4.22^{b}	3.56^{ab}	44.67^{ab}
Weed free	38.19^{a}	10.12^{a}	7.66^{a}	1.77^{a}	80.66^{a}	276.44^{a}	6.11^{a}	4.67^{a}	66.00^{a}
Treflan	21.30^{b}	5.24^{c}	2.84^{b}	0.64^{c}	76.00^{a}	164.89^{cb}	3.67^{cb}	1.56^{c}	22.55^{b}
Gallant Super	19.04^{bc}	5.14^{c}	4.07^{b}	0.96^{bc}	72.33^{a}	143^{cd}	3.56^{cb}	3.33^{abc}	29.34^{b}
Solarization	39.96^{a}	5.25^{c}	4.11^{b}	0.92^{bc}	79.89^{a}	140.67^{cd}	3.11^{cb}	2.45^{bc}	35.67^{b}
Level of significance	**	**	*	**	ns	**	**	*	*
CV%	17.94	16.86	36.84	34.81	9.00	19.43	21.81	38.03	24.32

PFW: plant fresh weight; PDW: plnat dry weight; IFW: Fresh weight of inflorescences, IDW: Dry weight of inflorescences; PH: Plant Height; NL: Number of leaves; NLB: Number of lateral branches; NFB: Number of flowering branches; NFP: number of flowers per plant. In a column figures with same letter (s) or without letter (s) do not differ significantly whereas figures with dissimilar letter are statistically different. ns = not significant, * = Significant at 5% level of probability, ** = Significant at 1% level of probability.

Variances analysis showed that plant height was not affected by weed control treatments. Weed control treatments significantly affected the number of leaves, so that the lowest number of leaves was recoded under no weeding condition, while the highest leaves number was obtained by complete weeding. Evaluation of lateral branches number showed that by increasing frequency of weeding the number of lateral branches significantly increased. The highest number of flowering branches was recorded in plant grown under weed free conditions and followed by T3 (2 hand weeding) and T4 (Gallant Super). Interestingly, the lowest number of flowering branches was obtained in plants grown under Treflan herbicide application (T5).

Assessment of stem diameter showed that the dragonhead plants under no weeding condition had the thinnest stems and one hand weeding could increase stem diameter up to 16% over weedy check condition. However, there was no significant difference between the other weed control treatments. Estimation showed that the length of flower organ in main stem significantly affected by weed control treatments and the longest flower organ was obtained from weed free, two hand weeding, solarization and Treflan treatments, respectively. However it seems that application of post-emergence herbicide negatively affected the length of flower organ; so that there was no significant difference between Gallant Super and no weeding. Mean comparison of canopy spread between the weed managements treatments revealed that by increasing frequency of weeding the canopy spread considerably increased.

Table 2. Influence of different weed control treatments on Morphophysiological traits and essential oil content of Moldavian dragonhead (*Dracocephalum moldavica* L).

weed control treatments	ST	LFO	CS	HFB	DIF	FWL	DWL	CHL	EOC	OY
No weeding	2.14^{c}	11.89^{d}	11.33^{e}	59.11^{a}	63.33^{d}	5.30^{d}	1.08^{d}	36.20^{c}	0.313^{d}	3.31^{d}
1 hand weeding	2.47^{bc}	13.55^{bcd}	16.22^{de}	62.56^{a}	69.67^{c}	6.30^{cd}	1.41^{b}	38.03^{bc}	0.380^{cd}	5.90^{bc}
2 hand weeding	2.75^{ab}	17.16^{ab}	25.89^{ab}	65.00^{a}	73.67^{b}	11.64^{b}	2.36^{ab}	41.93^{ab}	0.410^{bc}	9.74^{b}
Weed free	2.91^{a}	17.89^{a}	26.33^{a}	57.55^{a}	74.33^{b}	15.19^{a}	3.41^{a}	45.49^{a}	0.513^{a}	17.13^{a}
Treflan	2.71^{ab}	15.83^{abcd}	22.11^{abc}	59.22^{a}	78.00^{a}	8.90^{bc}	1.95^{bc}	39.42^{bc}	0.380^{cd}	6.57^{bc}
Gallant Super	2.64^{ab}	12.67^{cd}	20.56^{bcd}	55.44^{a}	64.33^{d}	7.17^{cd}	1.64^{cd}	36.31^{c}	0.383^{cd}	6.49^{bc}
Solarization	2.65^{ab}	15.94^{abc}	19.78^{de}	61.11^{a}	73.33^{b}	7.62^{cd}	1.57^{cd}	37.96^{bc}	0.477^{ab}	8.26^{b}
Level of significance	**	*	**	ns	**	**	**	**	**	*
CV%	7.25	14.97	15.56	11.34	1.53	19.13	8.28	6.79	9.67	36.78

ST: Stem diameter (cm); LFO: lengthof flower organin main stem (cm); CS: Canopy spread (cm), HFB: Height of the first flowering branche (cm); DIF: Number of days from planting to initiation of flowering; FWL: Fresh weight of leaves (g); DWL: Dry weight of leaves (g); CHL: chlorophyl content (SPAD unit); EOC: Essential oil content (mL 100 g^{-1} dried plant); OY: Oil yield (Kg ha^{-1}). In a column figures with same letter (s) or without letter (s) do not differ significantly whereas figures with dissimilar letter are statistically different. ns = not significant, * = Significant at 5% level of probability, ** = Significant at 1% level of probability.

Result showed that weed control treatments considerably affected the dragonhead phenology, so that the longest vegetative growth period recorded in plants grown under pre-emergent chemicals control (T5) and weed free condition. This finding corroborate the result of BOUTIN & al. [14] who reported that herbicides can cause marked delays in flowering times and significant reduction in flower production in many species. The highest fresh and dry weight of leaves was obtained by dragonhead plants grown under weed free condition and two times of hand weeding. However, there was no significant difference between chemical control and solarization (Table 2). Result showed that chlorophyll content in dragonhead leaves considerably influenced by weed control treatments. The lowest chlorophyll content was recorded under weedy check condition and pre-emergence herbicide application (36 SPAD unit), while the highest amount was obtained by plants grown under the weed free condition (45 SPAD unit). This finding is consistent with previous research (SPASOJEVIĆ al. [15]) who found that reduction of weed competition by proper agronomic managements could enhance leaf chlorophyll concentration of crop plant.

Assessments of the essential oils between different treatments revealed that changes tendency in quantity of essential oils was very similar to trend of plant fresh weight. The plants grown under complete weed control and/or soil solarization had the highest essential oil content (Table 2). It is interesting to note that there was no significant difference between the essential oil content of dragonhead plants grown under chemical control treatments (T_5 and T_6) and weedy check condition. These results are in accord with finding of WALKER & al. [16], which showed that weed control technology could affect the essential oil content of summer savory (*Satureja hortensis*). Trend analysis between oil yield and essential oil content revealed that there is a similar trend for both traits, so that complete weed control increased oil yield up to 5 times over weedy check condition. Data presented in Table 3, shows the correlation between the morpho-physiological traits of dragonhead. It can be noticed that there was significant positive relationship between plant dry weight, chlorophyll content, fresh weight of inflorescences, dry weight of inflorescences, number of leaves, number of lateral branches, number of flowers per plant, number of days from planting to initiation of flowering, fresh and dry weight of leaves and oil yield ($P<0.01$). Furthermore, there was significant positive relationship (correlation coefficient $\geq$ 80) between essential oil content and some traits such as chlorophyll content, plant fresh and dry weight, dry weight of inflorescences, stem diameter, number of flowers per plant and length of flower organ in main stem (Table 3). The present findings are in agreement with the results of RAHBARIAN and SALEHI SARDOEI [17] which showed a significant and positive correlation between dragonhead fresh weight, biomass, plant height and number of lateral branches.

In terms of the correlation result it is important to emphasize that a positive noticeable relationship was found between the essential oil yield and plant dry weight, fresh and dry weight of inflorescences, number of leaves, fresh and dry weight of leaves. The presence of a correlation between last mentioned traits and essential oil yield may refer to this point that these traits can be introduced as key traits for selection of high quality landrace and should be focused in breeding programs of dragonhead in the semiarid conditions. In addition, the principle component analysis (PCA) described a suitable amount of the total variation; the correlation coefficient between any two traits is approximated by the cosine of the angle between their vectors. In the Figure 1, the most prominent relations are: a strong positive association among essential oil yield, fresh and dry weight of inflorescences, number of lateral branches, number of flowers per plant, plant dry weight, fresh and dry weight of leaves; also among essential oil content, chlorophyll content, plant fresh weight, stem diameter and canopy spread as indicated by the small obtuse angles between their vectors ($r = \cos 0 = +1$). There was a no correlation between number of flowering branches and height of the first flowering branch as indicated by the near perpendicular vectors ($r = \cos 90 = 0$).

In current study 17 compounds were identified in the essential oil extracts from dragonhead plants grown one hand weeding conditions and represent 99.41% of the oils (Table 4). The results of both GC and GC–MS analyses of essential oils of dragonhead plants revealed that the major constituents of the oil were Neral, Geraniol, Geranial, and Geranyl acetate. These components on average represent 17.88%, 19.27%, 26.26% and 23.11% of the oils that were extracted from plants, respectively. It is encouraging to compare these compounds with that found by YOUSEFZADEH & al. [2] and DAVAZDAH-EMAMI& al. [18] who reported that the main components of essential oils extracted from dragonhead plants are Geraniol, Geranial, Geranyl acetate, Neryl acetate, cis Chrysanthenol and β-Pinene. Comparison of constituents of the oil between weed control treatments revealed that dragonhead plants grown in weedy check condition lacked 1-octen-3-ol. It is interesting to note dragonhead plants grown under weed free condition showed the highest numerical quantity of some compounds such as sabinene, 6-methyl-5-hepten-2-one, limonene, cis limonene oxide and neral. Moreover, the lowest numerical quantity of neryl acetate was recorded under complete weed free condition (Table 4).

Another very important point, which deserves attention, is that the highest numerical quantity of β-pinene and cis chrysanthenol was recorded under chemical control treatments (T_5 and T_6). However, the lowest value of neral was recorded for plants grown under chemical control. Result showed that by post-emergence application of Gallant carvacol and 6-methyl-5-hepten-2-one ($C_8H_{14}O$) were not detectable. Also in dragonhead plants grown under pre-emergence control (Treflan application) thymol was not detectable.

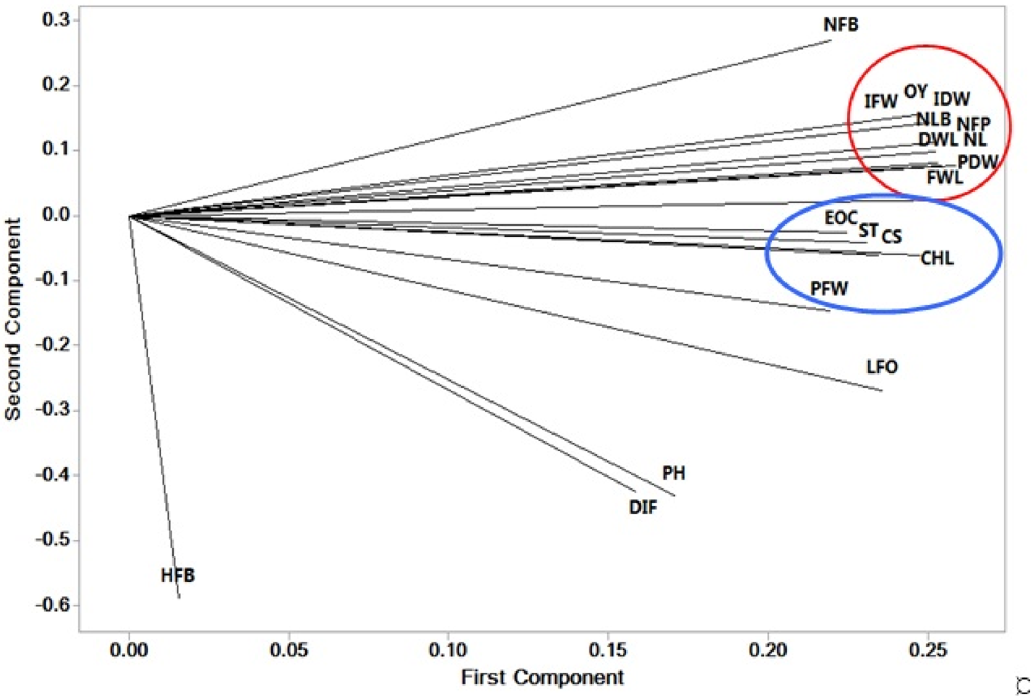

Figure 1. The principle component analysis (PCA) for morpho-physilogical traits of Moldavian dragonhead (*Dracocephalum moldavica* L).under different weed control mangments.

Table 3. Pearson's correlation coefficients among 18 traits of Moldavian dragonhead (*Dracocephalum moldavica* L).

	CHL	PFW	PDW	IDW	IFW	PH	NL	ST	NLB	NFB	NFP	LFO	CS	HFB	DIF	DWL	FWL	EOC
PFW	0.70																	
PDW	0.95	0.76																
IDW	0.87	0.76	0.97															
IFW	0.87	0.75	0.95	0.99														
PH	0.69	0.68	0.58	0.57	0.57													
NL	0.96	0.72	0.98	0.93	0.92	0.52												
ST	0.76	0.76	0.85	0.78	0.72	0.46	0.84											
NLB	0.91	0.71	0.98	0.92	0.89	0.45	0.97	0.91										
NFB	0.72	0.61	0.87	0.96	0.94	0.42	0.81	0.67	0.83									
NFP	0.90	0.82	0.97	0.99	0.99	0.62	0.93	0.75	0.90	0.91								
LFO	0.88	0.86	0.84	0.75	0.73	0.77	0.85	0.85	0.82	0.54	0.79							
CS	0.80	0.72	0.86	0.81	0.75	0.52	0.87	0.97	0.91	0.70	0.76	0.87						
HFB	0.15	0.16	-0.03	-0.03	-0.03	0.77	-0.07	-0.03	-0.14	-0.13	0.00	0.32	0.08					
DIF	0.65	0.62	0.53	0.35	0.31	0.60	0.57	0.72	0.57	0.10	0.40	0.86	0.69	0.35				
DWL	0.96	0.70	0.99	0.92	0.91	0.52	0.99	0.84	0.98	0.81	0.92	0.84	0.86	-0.08	0.57			
FWL	0.97	0.73	0.98	0.92	0.92	0.59	0.99	0.83	0.96	0.79	0.93	0.88	0.88	0.02	0.60	0.99		
EOC	0.71	0.95	0.81	0.81	0.78	0.57	0.75	0.80	0.79	0.69	0.85	0.80	0.71	-0.02	0.56	0.75	0.74	
OY	0.87	0.75	0.95	0.99	1.00	0.57	0.92	0.72	0.89	0.94	0.99	0.73	0.75	-0.03	0.31	0.91	0.92	0.78

† Critical values of correlation $P<0.05$ and $P<0.01$ (D.F. 16) are 0.47 and 0.60, respectively.

4. Discussion

The results showed that weed control treatments had a significant effect on growth characteristics and content of essential oil. Our finding revealed that the presence of weeds in the fields of medicinal can considerably affect herbage yield and active ingredients. Our result revealed that soil solarization could prevents the emergence of many annual weeds from the beginning of growth season, especially at the top layer because temperature increases more slowly at deeper depths. In other words, this treatment was able to significantly reduce the duration of weeds presence in the field. It appears that in such case there will be a minimum competition between weeds and medicinal plant. MARENCO and LUSTOSA [19] found that 15-45 days solarization period effectively controlled annual weeds in Brazil and its effectiveness was appreciable after one year. To reiterate, one the main aims of weed management in field of medicinal plants is maintain a favorable balance between quantity and quality of pharmaceutical active ingredients. Current results indicated that soil solarization may significantly affect the weed seed bank and if properly conducted it can be considered as highly effective weed management method in semi-arid region. In present study, in most of the studied growth characteristics the best performance was obtained by complete weed control (weed free), two times hand weeding and solarization treatments. The difference between one and two times hand weeding can be explained through the critical period for weed control (CPWC). In essence, CPWC is a period in the medicinal plant growth cycle during which weeds must be controlled to avoid yield reduction. It seems that second hand weeding (40 DAS) was most corresponded with CPWC and could provide critical weed-free period for dragonhead plants. Furthermore, it appears that 40 DAS is time span when dragonhead is most vulnerable.

Table 4. Oil composition of Moldavian dragonhead (*Dracocephalum moldavica* L.) affected by different weed control treatments.

weed control treatments	RI[a]	No weeding	1 hand weeding	2 hand weeding	Weed free	Treflan	Gallant Super	Solarization
Sabinene	964	0.21	1.06	1.12	2.03	1.04	0.64	1.62
1-Octen-3-ol	965	-	0.38	0.27	0.19	0.26	0.31	0.31
6-Methyl-5-hepten-2-one	978	0.31	0.2	0.31	0.64	0.18	-	0.42
β-Pinene	989	1.51	1.19	0.14	0.81	2.51	1.47	1.03
Limonene	1018	0.42	0.49	0.5	1.16	0.92	0.81	0.65
cis-Chrysanthenol	1056	1.09	0.79	0.85	0.93	2.69	3.21	1.29
Linalool	1109	0.71	1.03	0.92	1.47	0.83	0.36	0.81
cis Limonene oxide	1167	0.84	0.88	1.43	1.76	0.62	0.22	1.05
Citronellal	1171	0.41	0.26	0.19	0.33	0.15	0.19	0.28
Trancelimonene oxide	1180	1.59	1.3	1.25	1.58	1.69	3.3	1.74
Neral	1245	15.41	18.81	17.51	21.26	16.72	13.38	19.64
Geraniol	1267	19.36	20.51	21.18	16.86	16.81	18.26	22.05
Thymol	1273	0.24	0.49	1.27	0.2	-	1.5	0.86
Geranial	1289	28.91	28.06	25.41	26.29	29.32	26.71	21.81
Carvacol	1319	0.23	0.18	1.2	-	0.35	-	1.49
Neryl acetate	1335	2.52	1.18	1.16	0.37	1.69	2.15	0.73
Geranyl acetate	1357	23.65	22.6	23.38	22.51	22.55	24.72	22.95
Total		97.41	99.41	98.09	98.39	98.33	97.23	98.73

[a]RI, retention indices in elution order from DB-5 column.

Although the use of herbicides could control weeds to some extent and led to the release of resources, observation in this study revealed that active ingredients and probably the medicinal properties of dragonhead can be significantly affected by herbicides. From a physiological point of view, special attention should be given on possible side effects of applied herbicides on quality of the oil. Furthermore appropriate herbicide application timing is critical for determining their efficiency.

The leaves are the most delicate tissue and often contain the highest essential oil (DAVAZDAH-EMAMI & al. [18]), in current study the both chemical control treatments showed the lower fresh and dry weight of dragonhead leaves when compared with weed free and two hand weeding condition (T_3 and T_4). However, the reason for low efficiency of the chemical control compared to hand weeding (T3 and T4) is not completely clear. Although this result can be attributed to the presence of a wide range of broadleaf weeds and grasses, mismatching the application time of post-emergence herbicide with CPWC and rapid herbicide degradation.

Regardless of the side effects of herbicides on medicinal plant, to obtain maximum herbal yield post-emergence herbicides must be applied exactly at CPWC. Although such effect has not yet been quantified, it is likely that herbicides can reach to non-target plants and affect different developmental stages depending on their application time. However our finding showed that agrochemicals application could reduce the essential oil extracts from dragonhead plants. Considering the risk of contamination of end products with herbicide residues it seems that production of medicinal plants through ecological weed management will improve the quality of essential oil. The result of the current experiment revealed that non-chemical weed management (hand weeding and solarization) could be suitable technique for reducing weed pressure on high value herb, and the mentioned practices are potentially worthwhile option for dragonhead fields. The analyzing the current result and finding of previous field experiment indicate that the use of the herbicide tended to reduce dry matter content and some essential oils (UPADHYAY & al. [8]). Therefore, some concern should be linked to health certificate of the end products (especially when the production is addressed to direct human consumption) as affected by the application of chemical herbicides, since herbicide residuals have been detected on some herbal product (KOSALEC & al. [20]). However, our result suggested that alterations in competition between weeds and crops significantly affect the chemical composition of dragonhead. Interestingly between the main oil components the lowest geranial was observed at T_3 and T_7 where is thought there was the lowest competition. This suggests that reduction of competition will not always increase the amount of major constituents. In recognition of this fact, the highest value of neryl acetate was recorded under no weeding condition.

The main components of oil that affected by weed control treatments were neral, geraniol, geranial, and geranyl acetate. Geranial (3,7-dimethyl-2,6-octadienal) is a pair of terpenoids with the molecular formula $C_{10}H_{16}O$. The *E*-isomer is known as geranial or citral and it also has strong antimicrobial qualities and pheromonal effects in insects (ONAWUNMI [21]). Geranial and neral are isomer and they may justify some medicinal properties of dragonhead plant. It have been revealed that geraniol can be synthesized by geraniol synthesis from geranyl phosphate, than by a dehydrogenese and/or oxidase be converted to geranial (IIJIMA & al. [22]). It is likely that weed management treatments through the reduction of competition influenced the geraniol biosynthesis pathway. Our findings further support the idea of ARGYROPOULOU & al. [23] and AZIZ & al. [24] who reported that agro-technical approaches and ecological factors could affect the composition of essential oil extracts from medicinal and aromatic plants. Finally, it may rationally be argued that environmentally friendly approaches (soil solarization and hand weeding) rather than chemical control could solve the weed problem in dragonhead fields. According to the unique characteristics of dragonhead finding the best management strategy for reducing the weed negative effects should be seriously considered

5. Conclusion

In conclusion the results of this experiment showed that weed can severely reduce dragonhead growth, herbal yield and essential oil. In fact, weeds grow faster than native plants and successfully compete for available nutrients, water, space and sunlight. Weed management strategies that effectively increase the competitive ability of medicinal plants can be able to improve quality and quantity active ingredients and pharmaceutical materials. Our study showed that regular hand weeding and soil solarization could be assigned as best weed control options for dragonhead filed in northwest semi-arid region. The higher herb yield and essential oil volume harvested from plant grown under weed free and soil solarized condition could be attributed to efficient reduction of the weed-crop competition and increase the availability of natural resources, including light, soil nutrients, and soil moisture for medicinal plant. Although herbicides are effective tools for controlling weeds and can reduce costs associated with physical weed removal, their application may affect the constituents of the oils in medicinal plant and should be taken with caution. To take into account all the data concerning the effects of weed management on medicinal plants, assessment of active ingredients and investigation of the therapeutic properties is very important. Results revealed that the environmentally friendly technique for controlling weeds is an essential component of dragonhead production system.

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