



## Original Research

# The effect of weed control on growth, yield and physicochemical properties of valerian (*Valeriana officinalis* L.)

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### ABSTRACT

A limiting factor in valerian production is weed interference so, the crop protection from weed is essential. Field experiments were conducted for two consecutive seasons (2014-2015) to evaluate different weed control methods on growth, yield, and oil quality of valerian in Iran. The experimental design was a randomized block with 7 treatment and 4 replicates. Treatments included untreated control, manual weeding, barley straw, sorghum straw, wheat, black plastic and post-emergence oxadiargyl. The lowest density and dry weight of weeds was related to the manual weeding treatment. Result showed that the maximum growth parameters of valerian were obtained from manual weeding treatment followed by black plastic, barely straw and sorghum straw reflecting superior weed control. Essential oil analyses indicated that bornyl acetate, valerenal, camphene and  $\alpha$ -pinene were the most abundant constituents. These components on average represent 27.7, 14.7, 4.1 and 2.2% of the oils that were extracted from plant, respectively. Bornyl acetate, valerenal and camphene contents did not vary with the various studied treatments although there was a trend toward higher in manual weeding treatment. Overall finding of current experiments suggested that barely straw and sorghum straw are potential substitutes for manual weeding and black plastic mulch for weed control in valerian.

### Introduction

Today, due to the undesirable side effects of chemical drugs, the trend towards the use of herbal medicines is increasing. Valerian (*Valeriana officinalis* L.) is a perennial flowering medicinal plant native to Europe and Asia. Vigorous underground rhizomes of this species produce numerous cylindrical roots (Pop et al. 2010), which are used for their sedative properties with indications including nervous tension, insomnia, anxiety, and stress (Fernández et al. 2004; Circosta et al. 2007;

Patoka and Jakl, 2010). It is also used for treatment of hypertension and cardiac arrhythmia (Patoka and Jakl, 2010). Valerian reduces blood pressure and encourages sleep (Chevallier, 1996). Very little research on increasing production of medicinal plants have been done, so providing appropriate methods for increasing the quantity and quality of medicinal plants is important (Aliabadi Farahani et al. 2008). Iran is the best center for cultivating of medicinal plants in the world, considering the geographical and climatic conditions. Cultivation of medicinal plants in different stages of production faced a number of limitations such as flood, frost, wind, extreme heat, plant diseases and weeds (Vahedi, 2005). Weeds 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. Hand weeding is the most popular method of removing weeds of valerian in Iran but it is costly and time consuming method. Monjezi et al. (2015) suggested that oxadiargyl, haloxyfop-R and sethoxydim may be used safely for weed control of valerian in Iran and reported application of oxadiargyl resulted in no marked injury to valerian. The demand for integrated weed management approaches has resulted from increasing energy, labor, and material costs associated with weed control practices in conventional cropping systems (Feldman et al. 2000). Mulch is applied to the soil surface to create a physical barrier that inhibits weed seed germination and growth (Ferguson et al. 2008). Synthetic or organic mulch is a common technique for increasing profitability of many crops (Palada et al. 2000; Najafabadi et al. 2012). Conserving the soil moisture, suppressing the weeds, improving soil fertility (when organic mulch is used) and modifying the soil physical environment are advantages of mulching (Kashi et al. 2004). Different materials including organic materials, plastic materials and biodegradable Polyethylene could be used as mulch (Haapala et al. 2014). Organic mulches have also been used for *Citronella java* (Singh et al. 2001), basil (*Ocimum basilicum*) (Palada et al. 2000) and mulberry (*Morus indica* L.) (Shashidhar et al. 2009). Mulches can play an important weed control role in many vegetable crops (Richard et al. 2002) such as banana (Ssali et al. 2003), tomato (*Lycopersicon esculentum* L.) (Abdul-Baki et al. 1996; Rahman et al. 2006), potato (Boydston and Vaughn, 2002), pepper (Aiyelaagbe and Fawusi, 1986), lettuce (Ngouajio et al. 2003) and strawberry (Kumar and Dey, 2011). The effect of the surface mulch on the physical conditions of the soil surface layer is dependent on mulch type, quantity and structure (Teasdale and Mohler, 1993). The use of poaceae residues as mulch have been reported in the ecological agriculture for preventing weed seeds germination (Maldonado et al. 2001; Shiyam et al. 2011). Anzalone et al. 2010 stated that the best and worst organic mulch for weed control in tomato were rice (*Oryza sativa* L.) straw and absinth wormwood (*Artemisia verlotiorum* Lamotte) straw, respectively. Black polyethylene mulch inhibits germination and growth of most weeds species by preventing sunlight reaching the soil surface (Sinha, 2002). Black mulch increases the temperature

of the air and soil environment close to the plant as a result of the mulch's absorption of solar radiation. Polyethylene mulch conserves soil moisture (Anikwe et al. 2007; Kumar and Lal, 2012). Plastic mulch cause high weed control but causing a serious waste problem (Tabaglio et al. 2008) and few herbicides are available for valerian.

This study examines the effects of oxadiargyl herbicide, organic and synthetic mulch on weed suppression and in valerian growth parameters compared with manual weeding, positive and untreated control, negative controls. The other objective of my study was to evaluate the effect of the weed management treatments on the concentration of three target herbal compounds, bornyl acetate, valerenal and camphene in valerian plant.

## Material and Methods

### *Site and soil Information*

Two field experiments were carried out at the experimental farm field in Karaj, Iran, in 2014 and 2015. The field was located at 35° 45' N, 50° 39' E and an altitude of 1245 meter from sea level. The meteorological data recorded during the trial period are given in Table 1. The soil texture was clay loam (35% clay, 21% silt and 44% sand) with a pH of 7.4, and 0.8 % organic matter. The experimental field was ploughed 30-35 cm two times before planting by using moldboard, subsequently soil harrowed twice at 10 cm depth. Prior to planting, nitrogen (90 kg N/ha as NH<sub>4</sub>), phosphorus (80 kg/ha as P<sub>2</sub>O<sub>5</sub>), and potassium (100 kg/ha as K) were applied to base on the amount of available P and K in the soil prior to transplanting.

**Table 1.** Monthly temperature and precipitation during the growing season.

Year	Month	Average temperature (°C)			Precipitation (mm)
		Minimum	Maximum	Mean	
2014	July	21	38	29.5	0.06
	August	19	39	29	0.05
	September	17	33	25	0.2
	October	6	18	12	21
	November	3	15	9	50
2015	July	22	37	29.5	0.06
	August	17	35	26	0.05
	September	14	30	22	1
	October	5	17	11	36
	November	2	15	8.5	51

### *Trial establishment*

The used experimental scheme was a randomized complete block design with four replications and elementary plot size was 6×2.5 m<sup>2</sup>, each plot consisting of 5 rows 50 cm apart. 4-5 leaf stage seedlings were transplanted in the field on July 20 in 2014 and July 18 in 2015. The experiment comprised seven treatments including untreated control, manual weeding (weed free), barley straw (*Hordeum vulgare* L.) at 1 kg/m<sup>2</sup>, sorghum (*Sorghum bicolor* L.) straw at 1 kg/m<sup>2</sup>, wheat straw (*Triticum vulgare* L.) at 1 kg/m<sup>2</sup>, black plastic, and oxadiargyl at 30 g a.i./ kg. Herbicide was applied at the 5–6 leaf stages of the valerian plant.

### *Crop and weed Measurement*

The crop was harvested on 27 November in 2014 and on 23 November in 2015. Specific composition, density and weight of weeds were established by counting the weeds from 1 m<sup>2</sup> in each plot two times (30 days after transplanting (DAT) and before valerian harvest). Dry weight of weeds was determined by drying the weeds for 48 h in an oven at 75°C. Some of morphological traits such as flowering stem number, root diameter, root length and root yield were measured in ten plants from the middle of the plots. Valerian was harvested from 1 m<sup>2</sup> center area of the plots. After harvest, raw material was rinsed and cleaned, then rhizomes and roots were dried in a drying oven at a temperature of 35° C. The dried rhizomes and roots of valerian were powdered and hydrodistilled in a Clevenger-type apparatus for 3 h. The essential oils were dried over anhydrous sodium sulphate and stored at 3°C in a dark before analysis. The oils were analyzed by GC and GC/MS. The GC analyses were performed using a Perkin-Elmer (UK) 8500 gas chromatograph equipped with Flame Ionization Detector (FID) and a DB-5 fused silica column (30 m × 0.25 mm, film thickness 0.25 µm). Oven temperature was held at 60°C for 3 min and programmed to 275°C at a rate of 3°C/min; injector temperature (split: 1:25) 250°C; detector temperature, 280°C; carrier gas, N<sub>2</sub> at 12 psi. Varian 3700 chromatography equipped with a DB-5 column (25 m × 0.25 mm i.d., film thickness 0.39 µm) combined with a Varian MAT 44S, ionization energy 70eV. The carrier gas was He and injector temperature was 270 C. Approximately, 0.1 µl of neat oil was injected under split condition (100:1) and the oven temperature was held at 60 °C for 5min., programmed at 5 °C/min. to 220 °C and then holds at this temperature for 20 min. The compounds in the oil were identified by comparison of their retention indices (RI, DB-5) with those reported in the literature as well as by comparing their mass spectra with the Wiley GC–MS Library, Adams Library, Mass Finder 2.1 Library data, and published mass spectra data (McLafferty and Stauffer, 1989; Adams, 2007). The relative percentage of the oil compounds was expressed as percentages by FID peak area.

### *Data analysis*

Data were presented separately for both years. Bartlett's test was used to test for homogeneity of variance among treatments. Statistical analyses were performed using Statistical Analysis Systems (Version 9.1, SAS Institute Inc., Cary, NC) software. Differences were analyzed by ANOVA. Means were compared by the Fisher's Protected least significant difference (LSD) at the 5% level of probability. All experiments were done twice.

### **Results and Discussion**

Eighteen weed species were identified prior to harvest, of which 15 were annual (including thirteen dicotyledonous and two monocotyledonous). The most dominant weeds were common lambsquarters (*Chenopodium album* L.), green foxtail [*Setaria viridis* (L.) Beauv.], redroot pigweed (*Amaranthus retroflexus* L.), velvetleaf (*Abutilon theophrasti* Medik.), prostrate knotweed (*Polygonum aviculare* L.), (*Malcolmia africana* (L.) R. Br), large crabgrass (*Digitaria sanguinalis* L.), common cocklebur (*Xanthium strumarium* L.). The perennials weed included field bindweed (*Convolvulus arvensis* L.), common mallow (*Malva neglecta* Wallr.) and johnsongrass [*Sorghum halepense* (L.) Pers.].

### *Effect of treatments on weeds*

All treatments significantly reduced weed density compared to the untreated control. The highest weeds density in untreated control treatment may be due to the open niches available for weeds to germinate. At 30 DAT the best control of weeds was achieved with manual weeding in both years (Table 2). Black plastic and sorghum straw treatments also significantly reduced weed density compared to untreated control in 2014, indicating its effectiveness against weeds. In agreement with this result Majd et al. (2014) showed black and transparent plastic mulch significantly reduced total weed density and stated that this reduction be due to prevent reaching full light to light-dependent weeds for their germination. Barley straw, sorghum straw, black plastic and oxadiargyl treatments were effective treatments on reducing weed density and there were not significant differences among them in 2015. The best control of weeds was achieved with manual weeding followed by barley straw, sorghum straw and black plastic at harvest time in 2015. Weed density reduction by using straw mulch may be because of the release of allelopathic substance that inhibited weed seed germination. Preventing weed germination and growth with plant mulches by releasing allelopathic compounds or preventing the penetration of light to the soil surface have been reported by some researchers (Dhima et al. 2006; Judice et al. 2007). These results were in line with Kothari and Singh (1994) who reported significant reduction in weed density and dry

weight due to mulching in menthol mint (*Mentha piperita* L.). Similarly Abbas et al. (2018) reported that sorghum was more phytotoxic against *Phalaris minor* either alone or in a combination with herbicide mixtures as compared to sunflower (*Helianthus annuus* L.), rice and maize (*Zea mays* L.).

Weed dry weight was the highest in the untreated control compared with other control treatments owing to uncontrolled condition favored luxurious weed growth leading to increased weed dry weight in valerian production (Table 3). Manual weeding was the most effective treatment in reducing weed dry weight in both years. The reduction in weed dry weight with treatments might be due to a reduction in weed density. The lowest total dry weight was observed in valerian plants under manual weeding treatment followed by black plastic, barley straw and sorghum straw in 2015. There was no significant difference between manual weeding and black plastic in 2014. Black plastic mulch could reduce total dry weight of weeds 91% and 58% in comparison untreated control in 2014 and 2015, respectively. At harvest the use of barley straw mulch decreased weed density by about 80% comparing to untreated control treatment in 2015 (Table 3). Earlier studies showed the effectiveness of barley residues in reducing plant densities of eastern black nightshade (*Solanum ptycanthum* Dun.) by 98% and yellow foxtail [*Setaria glauca* (L.) Beauv.] by 81%, 30 days after planting the weed species (Creamer et al. 1996). Phenolic compounds are dominant compounds in barley. Phenolic acids have allelopathic activity on many plant species (Batish et al. 2001). Moreover this result was in agreement with researchers who found that mulch effectively controlled weeds without supplemental herbicides (Ramakrishna et al. 2006; Rowley et al. 2011). Oxadiargyl had also a significant impact on dry weight of weeds in valerian (Table 2). Weed density was lower in oxadiargyl treatment compared to the untreated control treatment.

**Table 2.** Effect of treatments on weed density (mean/m<sup>2</sup>) ± standard error in valerian crop, results of ANOVA and LSD test for means within year.

Treatments	30 DAT		At harvest time	
	2014	2015	2014	2015
Untreated control	24.87±2.1	23.59±3.5	60.83±2.6	66.93±3.1
Manual weeding	1.5±0.02	3.22±2.1	0.5±0.009	1.87±3.8
Barely straw	19.44±0	13.86±0	4.16±0	5.15±0
Sorghum straw	16.69±1.4	16.99±1	5.41±1.4	8.16±2.1
Wheat straw	21.59±0.9	22.32±0.9	18.47±1.4	46.51±1.6
Black plastic	15.53±0.75	18.66±0.8	1.22±1.2	8.97±1.9
Oxadiargyl	20.07±1.13	21.19±1.2	8.61±2.3	31.74±4.2
LSD	2.37	7.58	11.02	11.61

DAT: days after transplanting.

**Table 3.** Effect of treatments on weed dry weight (mean/m<sup>2</sup>) ± standard error in valerian crop, results of ANOVA and LSD test for means within year.

Treatments	30 DAT		At harvest	
	2014	2015	2014	2015
Untreated control	7.36±1.1	9.25±1.2	16.25±1	14.25±1.1
Manual weeding	1.0±0.004	3.25±0.67	0.5±0.007	1.25±0.31
Barely straw	1.39±0	3.89±0.5	5.5±0	4.0±0
Sorghum straw	1.66±0.5	4.19±0.34	6.0±0.8	2.75±0.55
Wheat straw	3.74±0.6	7.86±0.32	9.75±0.7	11.75±0.76
Black plastic	0.66±0.7	3.83±0.97	3.5±0.6	4.5±0.31
Oxadiargyl	2.36±0.4	6.61±0.45	7.25±1.2	9.5±1.2
LSD	0.97	1.08	2.05	1.81

#### *Effect of treatments on valerian plant*

Different weed control treatments significantly influenced number of flowering stem, root diameter, root length, root yield, essential oil content and essential oil yield of valerian (Table 4). In 2014 untreated control and wheat straw treatments produced the lowest flowering stem number (Table 4). The highest flowering stem number was observed under manual weeding treatment followed by black plastic mulch in 2015. The lowest root diameter of valerian plants was recorded under untreated control treatment and there were no significant differences among all other treatments in 2014. In 2015 the highest root diameter was recorded in manual weeding treatment followed by black plastic, wheat straw and barely straw. Assessment of root length showed that the valerian plants under manual weeding condition had the highest root length and followed by barley straw and sorghum straw in 2014. Manual weeding treatment produced the longest root of valerian in 2015. Valerian produced shorter roots in the oxadiargyl treatment in comparison manual weeding treatment. At harvest the use of barley straw mulch decreased weed density by about 80% comparing to untreated control treatment in 2015 (Table 4). Valerian produced shorter roots in the oxadiargyl treatment in comparison manual weeding treatment. It means that this species was not tolerated to oxadiargyl in contrast with the results of Monjezi et al. (2015). Oxadiargyl herbicide inhibits the enzyme which is in the pigment synthesis pathway (Boger and Wakabayashi, 1995). Mean comparison of root yield revealed that the highest value obtained from valerian plants grown under manual weeding condition and those received barely straw, black plastic, wheat straw and sorghum straw in 2014. The highest root yield was obtained by manual weeding followed by black plastic and barely straw in 2015 (Table 4). It has been reported that mulching had beneficial effects on growth and dry matter of crops (Gill et al. 1999; Shukla et al. 2000; Joy et al. 2001a,b). Higher

yield of many crops by black plastic have also been recorded (Ibarra et al. 2001; Kwabiah, 2004; Ban et al. 2009; Igbal et al. 2009; Mamkagh, 2009; Moreno et al. 2009; Rashidi et al. 2010; Berihun, 2011; Bhatt et al. 2011; Hatami et al. 2012; Kumar and Lal, 2012). Increasing in growth parameters of valerian maybe due to higher soil moisture content and soil temperature in black plastic treatment. Parmar et al. (2013) reported that the growth of watermelon (*Citrullus lanatus* thunb) increased in mulch because of the sufficient soil moisture near root zone and minimizing the evaporation. The essential oil content was lowest in oxadiargyl treatment followed by untreated control in 2014 and untreated control treatment in 2015 (Table 4).

**Table 4.** Effect of treatments on morphological traits of valerian, essential oil content and essential oil yield, results of ANOVA and LSD test for means  $\pm$  standard error within year.

Year	Treatments	Flowering stem number (stem/plant)	Root diameter (mm)	Root length (cm)	Root yield (Kg/ha)	Essential oil content%	Essential oil yield kg.ha <sup>-1</sup>
2014	Untreated control	4.24 $\pm$ 1.1	2.6 $\pm$ 0.12	15.76 $\pm$ 2.76	2390 $\pm$ 94.50	0.91 $\pm$ 0.54	27.57 $\pm$ 4.9
	Manual weeding	7.72 $\pm$ 1.4	3.9 $\pm$ 0.10	27.14 $\pm$ 5.1	4460 $\pm$ 45.62	1.73 $\pm$ 0.11	51.98 $\pm$ 4.3
	Barely straw	7.42 $\pm$ 1.1	3.72 $\pm$ 0.11	26.03 $\pm$ 3.35	4215 $\pm$ 87.67	1.66 $\pm$ 0.32	49.84 $\pm$ 5.3
	Sorghum straw	7.12 $\pm$ 1.6	3.65 $\pm$ 0.08	25.71 $\pm$ 4.7	4110 $\pm$ 66.71	1.65 $\pm$ 0.33	49.44 $\pm$ 3.1
	Wheat straw	4.22 $\pm$ 0.7	3.77 $\pm$ 0.07	23.94 $\pm$ 2.9	4135 $\pm$ 34.43	1.59 $\pm$ 0.16	48.46 $\pm$ 2.4
	Black plastic	7.36 $\pm$ 1.3	3.60 $\pm$ 0.12	25.06 $\pm$ 2.8	4140 $\pm$ 75.41	1.61 $\pm$ 0.34	47.77 $\pm$ 5.8
	Oxadiargyl	7.22 $\pm$ 1.0	3.77 $\pm$ 0.14	17.96 $\pm$ 4.1	3660 $\pm$ 100.55	0.92 $\pm$ 0.22	27.46 $\pm$ 3.2
	LSD	0.61	0.44	1.95	440.08	4.28	0.14
2015	Untreated control	3.52 $\pm$ 0.4	2.8 $\pm$ 0.23	16.08 $\pm$ 3.76	2995 $\pm$ 100.54	0.75 $\pm$ 0.15	22.58 $\pm$ 2.1
	Manual weeding	7.76 $\pm$ 1.1	3.62 $\pm$ 0.41	27.27 $\pm$ 2.16	4670 $\pm$ 80.34	1.40 $\pm$ 0.23	52.23 $\pm$ 3.5
	Barely straw	6.99 $\pm$ 1.3	3.8 $\pm$ 0.22	24.49 $\pm$ 3.90	4285 $\pm$ 99.50	1.18 $\pm$ 0.23	46.88 $\pm$ 4.2
	Sorghum straw	5.39 $\pm$ 0.8	3.77 $\pm$ 0.31	18.67 $\pm$ 3.89	4075 $\pm$ 67.50	1.39 $\pm$ 0.19	35.69 $\pm$ 3.2
	Wheat straw	4.68 $\pm$ 1.0	3.62 $\pm$ 0.50	17.85 $\pm$ 4.78	3570 $\pm$ 89.75	1.02 $\pm$ 0.31	30.69 $\pm$ 4.1
	Black plastic	6.24 $\pm$ 0.7	3.8 $\pm$ 0.42	21.76 $\pm$ 2.12	4320 $\pm$ 110.43	1.22 $\pm$ 0.32	41.63 $\pm$ 2.7
	Oxadiargyl	5.30 $\pm$ 1.0	3.3 $\pm$ 0.18	18.33 $\pm$ 3.67	3420 $\pm$ 87.52	1.16 $\pm$ 0.34	35.02 $\pm$ 3.3
	LSD	0.77	0.31	2.7	459.58	5.43	0.18



Weed growth caused 58% and 56% reduction in essential oil yield of valerian in 2016 and 2017, respectively. The reduction in oil yield owing to unrestricted weed growth was because of root diameter, root length, root yield and essential oil content. The essential oil yield was highest in valerian under manual weeding followed by sorghum straw and black plastic in 2015 (Table 4). These results are in accordance with Walker et al. (2006) who showed that weed control technology could affect the essential oil content of summer savory (*Satureja hortensis*). Similarly the basic oil components among 15 samples in study by Raal and Arak (2008) were bornyl acetate (2.9–33.7%),  $\alpha$ -fenchene (0–28.3%), valerianol (0.2–18.2%), valeranal (tr–15.6%), isovaleric acid (0–13.1%), camphene (0–11.1%) and valeranone (0.5–10.9%). The oil quality of valerian oil did not vary with the various studied treatments. Similarly essential oil of rosemary (*Rosmarinus officinalis* L.) was not influenced by the application of organic mulch and N fertilization in the research by Singh (2013). My findings further support the result of Kothari et al. (2002) who reported that none of the treatments impaired the quality of rose-scented geranium (*Pelargonium* spp) oil measured in terms of citronellol and geraniol contents. Enhancement in the essential oil content of valerian as affected by various weed control methods may be attributed to better nutrition of the valerian which play a major role in improving oil value of valerian. Increased oil content in soybean [*Glycine max* (L.) Merrill] under weed control treatments has been reported by EL-Metwally and Shalby (2007). The essential oil yield was highest in valerian under manual weeding followed by sorghum straw and black plastic in 2015. These results are in accordance with Walker et al. (2006) who showed that weed control technology could affect the essential oil content of summer savory (*Satureja hortensis*).

#### *Effect of treatments on oil constituents of valerian plant*

In current study 46 compounds were identified in the essential oil contents from valerian plants grown under manual weeding condition and represent 95.83% of the oils (Table 5). Many researchers studied the composition of valerian root oil (Morazzoni and Bombardelli 1995; Pavlovic et al. 2004; Lopes et al. 2005).  $\alpha$ -pinene,  $\alpha$ -fenchene, camphene, bornyl acetate, myrtenyl acetate, myrtenyl isovalerate, valeranal, valerenone, valerenol, valerenyl acetate were the major constituents of valerian roots (Lopes et al. 2005; Pavlovic et al. 2004; Letchamo et al. 2004). Usually, bornyl acetate is the main constituent of the oil (Wichtl, 1994). The results of both GC and GC–MS analyses of essential oil of valerian plant revealed that the major constituents of the oil were bornyl acetate, valeranal, camphene and  $\alpha$ -pinene. These components on average represent 27.7%, 14.7%, 4.1% and 2.2% of the oils that were extracted from plant, respectively. The oil quality of

valerian measured in terms of bornyl acetate, valeranal, camphene content of oil did not vary with the various studied treatments (Table 6).

**Table 5.** Percentage composition of the essential oils of underground parts in valerian plants.

Number	Compound	IR	% (v/v)
1	$\alpha$ -pinene	929	2.2
2	$\alpha$ -fenchene	952	1.1
3	camphene	954	4.1
4	3-methyl valeric acid	960	0.8
5	sabinene	978	0.9
6	$\beta$ -pinene	982	1.2
7	<i>P</i> -cymene	1022	0.9
8	limonene	1025	0.87
9	$\beta$ -phellandrene	1030	0.76
10	$\gamma$ -terpinene	1056	0.6
11	naphtalene	1120	0.6
12	camphor	1140	1.4
13	borneol	1160	0.8
14	pulegone	1178	0.8
15	terpinen-4-ol	1180	0.9
16	$\alpha$ -terpineol	1185	0.8
17	myrtenol	1190	1.1
18	E-carveol	1099	1.0
19	thymyl methyl ether	1101	1.0
20	carvacrol methyl ether	1129	1.0
21	bornyl acetate	1145	27.7
22	<i>trans</i> - pinocarvyl acetate	1211	1.3
23	myrtenyl acetate	1234	1.2
24	terpenyl acetate	1267	1.1
25	<i>cis</i> -caryophyllene	1298	0.9
26	<i>cis</i> -carvyl acetate	1302	1.2
27	$\alpha$ -copaene	1321	1.3
28	italicene	1356	1.5
29	$\beta$ -cedrene	1359	1.4
30	$\beta$ -caryophyllene	1370	1.2
31	$\beta$ -gurjunene	1401	1.5
32	$\alpha$ -cedrene	1421	1.6
33	aromadenderne	1432	1.3
34	$\alpha$ -bulnesene	1496	1.8
35	bornyl isovalerate	1500	1.3
36	germacerene D	1503	1.0
37	(E,E)- $\alpha$ -farensene	1510	0.7
38	$\alpha$ -calacorene	1530	0.8
39	germacrene B	1554	0.8
40	longipinanol	1567	0.9
41	neryl isovalerate	1560	1.0
45	humulene epoxide II	1590	1.1
43	T-muurolol	1641	0.8
44	$\alpha$ -bisabolol	1681	4.0
45	valerenic acid	1699	0.9
46	valeranal	1700	14.7
Total	-	-	95.83

**Table 6.** Effect of treatment on oil Compound of valerian and results of ANOVA.

Treatments	Oil compounds combined for 2014 and 2015		
	bornyl acetate	valerenal	camphene
Untreated control	26.3	13.9	3.8
Manual weeding	27.7	14.7	4.1
Barely straw	27.1	14.2	3.9
Sorghum straw	27.2	14.6	4.1
Wheat straw	26.8	14.3	4.0
Black plastic	26.9	14.5	4.1
Oxadiargyl	26.5	14.6	4.0
Level of significance	n.s	n.s	n.s

n.s = Not significant at 5% level of probability

## Conclusion

The results of this experiment showed that weed can severely reduce valerian growth, essential oil content and essential oil yield. In fact, weeds grow faster than valerian plants and successfully compete for available water, nutrients and sunlight. Maximum growth parameters of valerian were obtained from manual weeding treatment followed by black plastic, barely straw and sorghum straw reflecting superior weed control. Essential oil analyses indicated that bornyl acetate, valerenal, camphene and  $\alpha$ -pinene were the most abundant constituents. These components on average represent 27.7%, 14.7%, 4.1% and 2.2% of the oils that were extracted from plant, respectively. The oil quality of valerian measured in terms of bornyl acetate, valerenal, camphene contents of oil did not vary with the various studied treatments although there was a trend toward higher in manual weeding treatment.

## Conflicts of Interest

The authors confirm that there are no known conflicts of interest associated with this study and there has been no significant financial support for this work that could have influenced its outcome.

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