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Effects of irrigation regime and plant density on harvest index of German chamomile (*Matricaria chamomilla* L.)

Alireza Pirzad[*1], Mohammad Reza Shakiba[2], Saeed Zehtab-Salmasi[2], Seyed Abolghasem Mohammadi[2], Hashem Hadi[1], Reza Darvishzadeh[1]

[1]Department of Agronomy and Plant Breeding, Faculty of Agriculture, Urmia University, Urmia, Iran
[2]Department of Agronomy and Plant Breeding, Faculty of Agriculture, Tabriz University, Tabriz, Iran

[*] Corresponding author: a.pirzad@urmia.ac.ir

Abstract

A two-year factorial experiment was conducted in Randomized Complete Block Design to evaluate the effect of irrigation regimes on the yield of biomass, dried flower, essential oil and seed, and harvest index of dried flower, essential oil and seeds of German chamomile at different plant densities. Factors applied were irrigation regimes (irrigation at 25, 50, 75, and 100 mm evaporation from pan class A) and plant density (5, 10, 15, 20 and 25 cm intra-row spaces with 30 cm inter-row space) with three replications. Results showed the significant effect of irrigation and plant density on the yield and harvest index of dried flower, essential oil and biomass. The highest yield of dried flower (1,136 kg/ha) was obtained from irrigation at 50 mm evaporation from pan, followed by 75, 25 and 100 mm evaporation, respectively. The highest (7,474 g/ha) and lowest (5,812 g/ha) essential oil yield were obtained from irrigation at 50 and 100 mm evaporation, respectively. The greatest biomass (2,989 kg/ha) observed at 25 mm evaporation, as well as irrigation at 50 and 75 mm and the minimum (1,882kg/ha) was at 100 mm. The highest yield of dried flower (1,241 kg/ha), essential oil (8,057 g/ha), seed (765 kg/ha) and biomass (2,716kg/ha) were obtained from 10 cm intra-row distance, whereas the lowest yield of dried flower (765 kg/ha), essential oil (4,921 g/ha) and seed (574 kg/ha) observed at 25 cm distance. The minimum biomass (1,768 kg/ha) was obtained from 5 cm intra-row space. The maximum (39%) and minimum (33%) harvest index of dried flower were obtained from irrigation at 100 and 25 mm evaporation, while the highest (47%) and lowest (29%) harvest index belonged to 5 and 25 cm planting spaces, respectively. The largest and smallest harvest index of essential oil concerned to 5 (0.324%) and 25 cm (0.192%), respectively. Our finding showed that the best irrigation was irrigation at 50 mm evaporation from pan and the optimal plant distance was 10 cm intra-row space.

Keywords: dried flower; essential oil; *Matricaria recutita*; plant population; seed; water.

Introduction

Plant harvest index (HI; proportion of economic yield to aerial dry weight), is an important trait associated with the dramatic increase in crop yield that have been proposed in the recent years. Harvest index reflects the partitioning of photosynthates between the grains and the vegetative parts, and improvements in harvest index emphasize on carbon allocation in grain production (Sinclair, 1998). The harvest index may be reduced on soils with decreasing water supply (Bolaños and Edmeads, 1993). The higher stress and plant density tolerance of modern hybrids may be associated with a lower shoot biomass threshold value for grain yield (Echarte and Andrade, 2003). High water availability promoted vegetative growth and decreased the harvest index in faba bean. The decreases in HI were more pronounced in the indeterminates, with reductions up to 48%, compared to 25% in the determinates (De Costa et al., 1997). Drought is common in tropical environments, and selection for drought tolerance is a way of reducing the impacts of water deficit on crop yield. Improved drought tolerance was attributed to simultaneous selection in well-watered environments and under carefully managed water stress conditions especially at flowering stage, resulting in greater partitioning of biomass to the ear and increased harvest index (Edmeades et al., 1999). There are some reports that show harvest index does and does not increase with increment in plant size and density (Mott and Mc Nei, 1995; Prihar and Steward, 1991). Variation in density in stands would affect inter branch competition and hence offers scope for increasing seed yields that affect harvest index of individual branches (Siddique et al., 1984). Chamomile (*Matricaria recutita* L.) is a medicinal plant that contains a large number of therapeutically and active compounds. The most important ones are the essential oil and flavonoid fractions. The essential oil is present in all organs of the chamomile plant. The flowers and flower heads are the main organs of the production of essential oil (Franke and Schilcher, 2005). High soil moisture caused by intense rainfall or poor drainage may restrict chamomile growth. The young plants, as well as old ones will turn yellow, wilt, collapse, and die under high soil moisture condition. There is also an increased risk of root rots. Periods of drought may lead to loss of second and the following harvests. Depending on the soil structure and related water supply, plants are likely to get scorched after the first harvest and may die (Franke and Schilcher, 2005). The chamomile *cv.* "Bodegold" reaches maximum essential oil content when the flowering head has almost flourished. The lower parts of the flowering head are already hollow; a daily periodic growth movement, however, is still notable. Chamomile is a plant that germinates in light (Bottcher et al., 2001). Based on our knowledge, information about the response of German chamomile to irrigation and another important factor affecting water use of plant (ie. plant density) are scarce. The main objective of the present study was to find out the effect of irrigation regime and plant population density on the biological and economical yield (dried flower, seed and essential oil), and harvest index of *Matricaria recutita* L.

Results

Yield of dried flower

Irrigation regime and plant density have significant effects ($P<0.01$) on the yield of dried flower (Table 3). Means comparison indicated that the maximum dried flower yield (1,136 kg/ha) produced by I_2 followed by I_3 (irrigation at 50 and 75mm evaporation from class A pan, respectively). The minimum yield (904 kg/ha) caused by I_4 treatment (irrigation at 100mm evaporation from class A pan). Irrigation at 25mm evaporation from class A pan (I_1) produced lower yield compared to I_2 and I_3, but higher than I_4 (Fig 1-A). The maximum yield of dried flower (1,241kg/ha) obtained from D_2 (10cm intra-row spacing), whereas other treatments produced lower yields. So that minimum yield (765kg/ha) obtained from 25cm intra-row spacing (Fig 1-B).

Yield of essential oil

Irrigation regime and plant density have significant effects ($P<0.01$) on the yield of essential oil (Table 3). Maximum yield (7,474 g/ha) was obtained from I_2; Irrigation at 50 mm evaporation from class A pan, and the minimum yield (5,812 g/ha) obtained from irrigation at 100 (I_4) and 25 mm (I_1) evaporation from class A pan, respectively. However, essential oil yield at I_3 was less than I_2 (Fig 1-C). The maximum yield of essential oil (8,057 g/ha) obtained from D_2 (10 cm intra-row spacing), decreased with any changes in density, so that the minimum one (4,921 g/ha) was obtained from D_5 (25cm intra-row spacing) (Fig 1-D).

Seed Yield

Irrigation regime had no significant effect on the yield of chamomile seed, whereas seed yield significantly affected ($P<0.05$) by plant density (Table 3; Fig 1-E). The lowest yield of seed (574 kg/ha) was obtained from D_5 (25 cm intra-row spacing), increased by decreasing intra-raw distance and gave a maximum value (765 kg/ha) at D_2 (10cm intra-row spacing). After that, dense planting (5cm intra-row spacing) led to decreased yield because of competition (Fig 1-F).

Yield of biomass

Irrigation regime and plant density have significant effects ($P<0.01$) on the biomass yield (Table 3). Maximum yield (2,989 kg/ha) was obtained from I_1, I_2 and I_3 treatment, and the minimum (1,882 kg/ha) obtained from I_4 treatment, respectively (Fig 1-G). However, maximum biomass (2,716 kg/ha) was obtained from D_2, D_3, D_4 and D_5 treatments, and the minimum (1,768 kg/ha) produced by D_1 treatment (Fig 1-H). It seems that, water deficit could have been reduced biomass only in severe stress (I_4). There are no changes on biomass among different plant densities, except D_1 treatment because of great competition (Fig 1-H). There are several reports on significant effects of irrigation (Begum and Paul, 1993; Cox and Julliof, 1986; El-Kheir et al., 1994; Mendoza, 1986) and plant density (Naghdi Badi et al., 2004; Shalby and Razin, 1992) on biological yield of some plants.

Harvest Index of dried flower

Irrigation regime and plant density have significant effects ($P<0.01$) on the HI of dried flower (Table 3). Our results showed that the maximum amount of HI (39%) was obtained from I_2, I_3 and I_4 treatments, and the minimum amount (33%) obtained from I_1 treatment. The minimum amount of HI resulted in lower yield of dried flower at I_1 treatment, in contrast the maximum amount of HI in I_2 and I_3 treatments resulted in maximum yield of dried flower. Despite of lowest yield of dried flower, the great amount of HI at I_4 resulted in lowest yield of biomass (Fig 2-A). The lowest yield of biomass led to maximum amount of HI (47%) in D_1 treatment. The highest yield of dried flower and biomass produced in D_2 treatment, lead to large amount of HI. Maximum biomass and reduced yield of dried flower lead to the lowest amounts of HI (29%) at D_3, D_4 and D_5, so that D_5 treatments had minimum amount of HI value (Fig 2-B).

Harvest Index of essential oil

Analysis of variance showed significant effects of irrigation regime ($P<0.05$) and plant density ($P<0.01$) on the Harvest Index of essential oil (Table 3). But, mean comparison indicated no significant difference between levels of irrigation regimes on HI of essential oil (Fig 2-C). The maximum amount of HI (0.324%) was obtained from D_1 treatment and increasing the intra-row distance, till D_5 caused the minimum amount of HI (0.192%). The highest amount of biomass and essential oil, and the lowest yield of essential oil lead to maximum and minimum HI in D_1 and D_5, respectively (Fig 2-D).

Table1. Rainfall, evaporation, air temperature, relative humidity and GDDs of German chamomile growth in experiment site at 2 years

Month	2003					2004				
	rainfall (mm)	evaporation (mm)	air temperature (° C)	relative humidity (R.H.) (%)	Growth Degree-Days (GDDs)	rainfall (mm)	evaporation (mm)	air temperature (° C)	relative humidity (R.H.) (%)	Growth Degree-Days (GDDs)
May	9	181.1	15.60	55.71	280.9	60	165.1	14.80	62.65	257.4
June	5.9	200.2	16.55	52.23	301.6	3.3	230.1	19.93	52.07	402.9
July	0	272.0	23.37	51.65	523.1	16.3	227.3	22.07	56.81	482.6
August	0	296.9	23.37	51.29	822.8	0	271.8	23.18	49.90	517.2

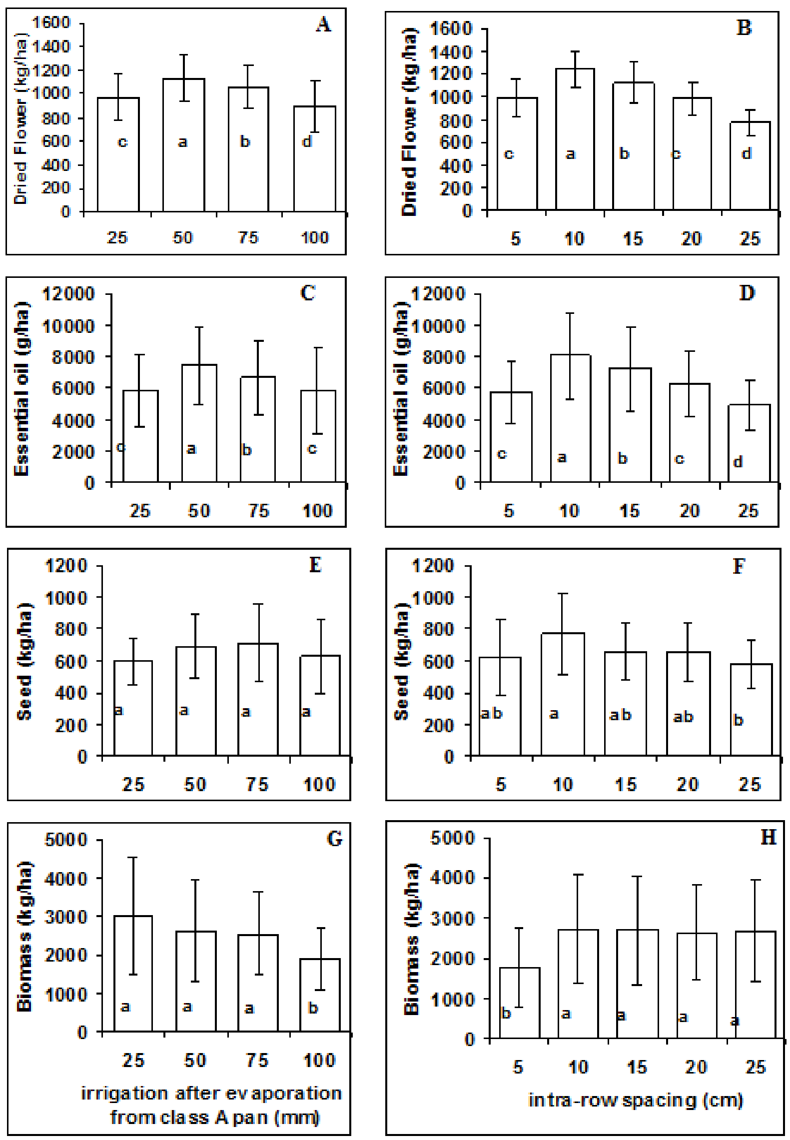

Fig 1. Mean comparisons of dried flower (A and B), essential oil (C and D), seed (E and F) and biomass (G and H) yield of *Matricaria recutita* L. at different irrigation regimes and plant densities, respectively. The same letters show non-significant differences.

Harvest Index of seed

Irrigation regime ($P<0.01$) and plant density ($P<0.05$) have significant effects on the HI of seed (Table 3). Changes in HI of seed showed same trend as the HI of dried flower because both HI have the same respective yield under irrigation regimes. So, the highest (27%) and lowest (20%) harvest index were obtained from irrigation at 100 and 25 mm evaporation from class A pan, respectively (Fig 2-E). However, maximum amount of HI (28%) was obtained by application of 5 cm intra-raw distance (D_1). Other 4 treats, D_2, D_3, D_4 and D_5 produced minimum amounts of HI (21%) as have been produced the minimum amount of biomass yield (Fig 2-F). Conversely, in spite of any significant difference of seed yield, between irrigation, mean comparison showed difference among irrigation on HI. Thus, I_1 produced the minimum amount of HI and other three treats produced the maximum amount of HI (Fig 2-E).

Discussion

The maximum dried flower and essential oil yield produced by irrigation at 50 mm evaporation from pan class A, and reducing trend caused in high and low water availability recognizing German chamomile as a mesophyte. The same biomass produced in irrigation at 25, 50 and 75 mm and the lowest biomass obtained at 100 mm evaporation, led to reduction of harvest index of dried flower in irrigation at 25 mm evaporation. Non significant effect of irrigation on seed yield categorized the harvest index of seed only in two groups. Previous results clearly indicated that any change in the amount of irrigation water in optimum condition reduces the yield of *Matricaria recutita* L. and *Fumaria purpurea* (Omidbaigi, 1993), and *Atropa belladonna* (Baricevic et al., 1999). Water deficit reduces plant photosynthesis by closing stomata, decreasing leaf area, stomata gravity, chloroplast and protoplast hydration, and protein and chlorophyll synthesis. However, reducing of photosyntate transport accumulates the products in leaves results in diminution in photosynthesis, limiting growth and crop yield (Hornok, 1992; Levitt, 1980). In water lodging condition, limitation of soil oxygen, confuses the respiration metabolism, root penetration, water and nutrient uptake as well as phytohormones and then reduces photosynthesis, growth and crop yield (Hopkins and Hüner, 2004; Rao et al., 1987). Despite of increase in the percentage of essential oil under slight water stresses (Pirzad et al., 2006; Simon et al., 1992; Solinas et al., 1996), yield of essential oil have a significant decrease in some medicinal plants such as mint (Charles et al., 1990; Muni Ram and Singh, 1995) and sweet basil (Refaat and Saleh, 1997). Reduction of essential oil yield under water deficit (50% Field Capacity) and water logging (90% Field Capacity) conditions compared to optimal irrigation regimes (70% Field Capacity) was reported in *Thymus vulgaris* (Letchamo and Gosselin, 1996). The highest yield of dried flower, essential oil, and seed produced in 10 cm intra-row distance led to maximum harvest index in 5 cm plant space because of the highest biomass of this treatment. The great value of biomass in comparison with fraction caused a converse trend of dried flower, essential oil and seed yield versus harvest index. Yield reduction, however, reported by any changes in plant density compared with optimal one (Douglas et al., 1996; Lloveras et al., 2004). There are some reports on producing same yield in narrow ranges of densities (Sharratt and Gesch, 2004). The optimal plant densities for German chamomile were reported for 10 to 80 cm spaces between rows in different condition (Salamon, 1992; Wagner, 1993). A maximal row distance of 70 cm is recommended, corresponding to a plant distance of 30 cm. Flower yield per hectare increases in to a degree, by which the row distance gets smaller. The yield per plant, however, increases with the enlargement of the distance. An enlargement of the distance would reduce the harvest value, whereas azulene and essential oil content are independent from the date of sowing, the row distance, and the quantity of seeds used. The flower heads are always located at the end of the side shoots. The more shoots a plant has, the higher quantity of flowers. Lack of light, a distance too close, and a soil too flat prevent the formation of side shoots, so that the plants grow with only one shoot (Franke and Schilcher, 2005). Likewise our results, decreasing yields of essential oil along with deviation from optimal plant density were reported in *Thymus vulgaris* (Naghdi Badi et al., 2004; Shalby and Razin, 1992).

Materials and methods

Experimental Site

This experiment was set up at the Research Farm of Urmia University, Urmia, Iran (latitude 37°, 53' N, 45°, 08' E, Altitude 1320 m above sea level). Climate condition of experimental site and soil characters were presented in Tables 1 and 2, respectively.

Plant materials

Seeds of *Matricaria recutita* L. *cv*. Bodegold, a tetraploide variety, were planted by hand in 2×4 m plots, on 1st May in two years. Hand control of weeds was carried out during the experimental period. The harvested crop consisted of typical freshly gathered flower heads, with approximately = 10% of flowers containing fragments of the small flower stalks, which were up to 30 mm long (Bottcher et al., 2001). Seeds were harvested and dried two times per year. Biological yield included leaves, stems, and flowers were fractionated and these separated parts were dried at 75 ◦C for the dry weight determination.

Treatments

A two-year factorial experiment was carried out in randomized complete block design with three replications. Factors were irrigation regimes (Irrigation at 25, 50, 75 and 100 mm evaporation from class A pan, I_1, I_2, I_3 and I_4, respectively) and plant densities (5, 10, 15, 20 and 25 cm intra-row spaces and 30 cm inter-row space, D_1, D_2, D_3, D_4 and D_5, respectively).

Isolation of Essential Oil

The air-dried parts of chamomile (15 g of the dry sample) were hydro-distilled in a Clevenger-type apparatus in

Table2. Soil analysis of experiment site

Soil Depth (cm)	Soil Texture	Silt- Clay-Sand (%)	Field capacity (%)	ρ (g/cm^3)	Organic mater (%)	Organic Carbon (%)	N (%)	P (mg/kg)	K (mg/kg)	EC (ds/ m)	pH
0-30	Clay-Loam	28-33-40	22.5	1.514	1.98	0.88	0.20	21	449.5	0.455	7.6
30-60	Clay-Loam	29-36-36	22.5	1.571	1.34	0.60	0.18	6.5	335.5	0.630	7.6

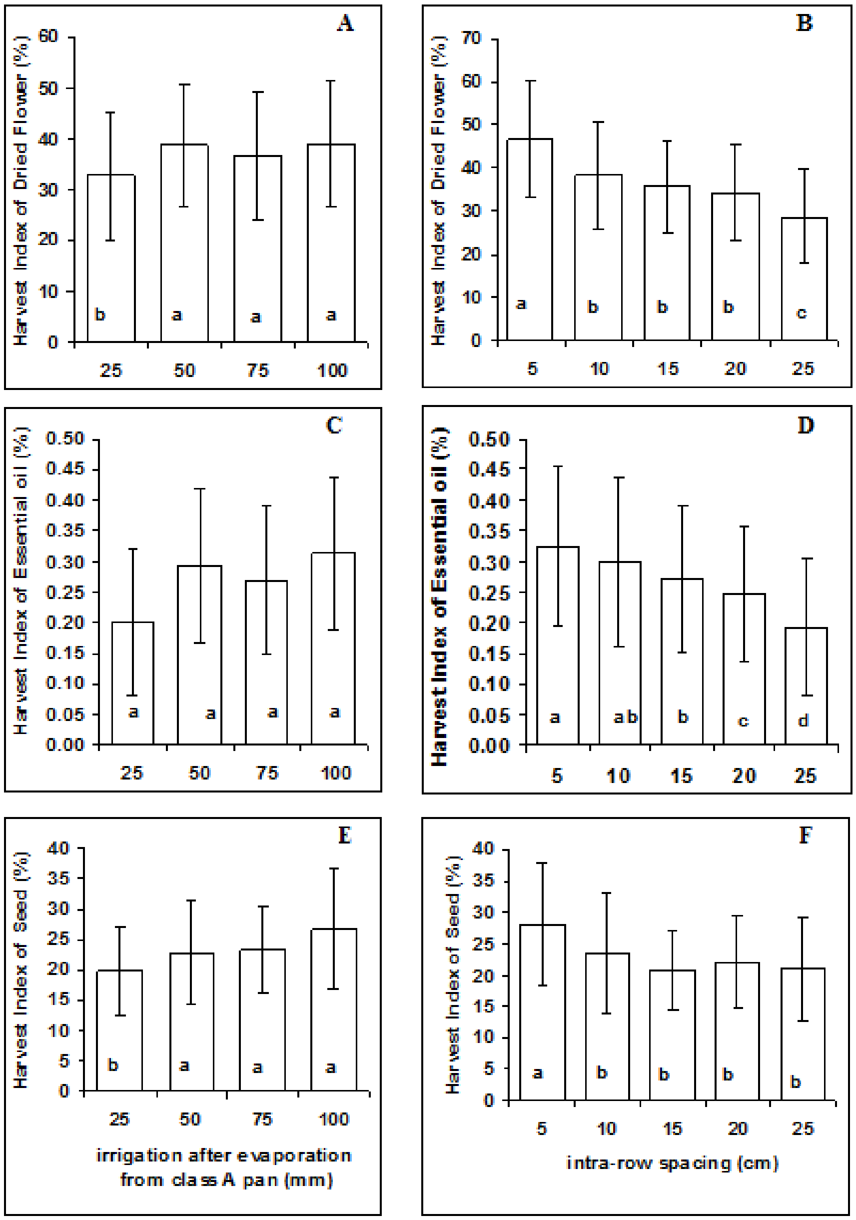

Fig 2. Comparison of means of dried flower (A and B), essential oil (C and D) and seed (E and F) Harvest Index of *Matricaria recutita* L. at different irrigation regimes and plant densities. The same letters show non-significant differences.

Table3. Analysis of variance of Yield and Harvest Index of *Matricaria recutita* L. affected by irrigation regimes and intra-raw space

Source of Variation	df	Yield				Harvest Index		
		Dried Flower	Essential oil	Seed	Biomass	Dried Flower	Essential oil	Seed
Year (Y)	1	304211.2*	1.998**	0.103^{ns}	2.587**	1.9320**	0.4370**	0.6850^{ns}
R(Y)	4	24770.7	0.018	0.045	0.049	0.0143	0.0030	0.1190
Irrigation(A)	2	311577.1**	0.112**	0.033^{ns}	0.173**	0.0557**	0.006^{*}	0.1047^{**}
A×Y	2	33475.1^{ns}	0.016^{ns}	0.012^{ns}	0.009^{ns}	0.0063^{ns}	0.001^{ns}	0.0250^{ns}
Intra-raw space(B)	4	751772.8**	0.161**	0.050*	0.203**	0.1560**	0.010**	0.0643^{*}
B×Y	4	1948.8^{ns}	0.002^{ns}	0.025^{ns}	0.011^{ns}	0.0045^{ns}	0.002^{ns}	0.0355^{ns}
A×B	12	1291.1^{ns}	0.002^{ns}	0.028^{ns}	0.027^{ns}	0.0101^{ns}	0.002^{ns}	0.0328^{ns}
A×B×Y	12	566.6^{ns}	0.001^{ns}	0.018^{ns}	0.035^{ns}	0.0138^{ns}	0.003^{ns}	0.0151^{ns}
Error	76	17404.9	0.007	0.015	0.021	0.0111	0.002	0.0209
Coefficient of Variation		12.93	2.22	2.56	2.71	6.90	3.48	10.92

ns, * and ** ; non-significant, significant at 5 and 1% ; df, degree of freedom

1000 mL round bottomed flask with 600mL de ionized water for 4h (Letchamo, 1990).

Harvest Index (HI)

Harvest index was calculated as total dried flower, essential oil and seed weight divided by total above-ground plant dry weight for harvest index of dried flower, essential oil and seed production, respectively.

Statistical Analysis

Combined analysis of variance, appropriate for a two-year factorial experiment, based on randomized complete block design was done, using MSTATC statistical package. Student-Neuman Keul's test (SNK) was used to evaluate differences between treatments.

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