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# Optimal plant spacing of *Lallemantia iberica* under rainfed and supplementary irrigation

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**ABSTRACT**

To evaluate the optimal sowing distances in rainfed and supplementary irrigation conditions for the yield and yield components of Dragon's head (*Lallemantia iberica* L.), a factorial experiment was conducted based on randomized complete block design with three replications at Urmia University in 2014. Treatments were sowing distances (15 and 30 cm inter-row and 1 and 2 cm intra-row) and irrigation (rainfed and supplementary irrigation). The highest number of leaves (105 Nplant$^{-1}$) and the highest Leaf (1961 mg plant$^{-1}$) and flower (242 mg plant$^{-1}$) weight were obtained from wide inter (30 cm) and intra (2 cm) rows with supplementary irrigation. Supplementary irrigation resulted in the maximum plant height (43.7 cm) and 1000-Seed weight (4.96 g). Means comparison showed that the highest values of seed yield (2730 kg ha$^{-1}$) were obtained in supplementary irrigation with narrow inter (15 cm) and wide intra (2 cm) row distances. The maximum biological yield (4935 kg ha$^{-1}$) and harvest index (52%) were found in 15 cm inter-row spacing treatment with supplementary irrigation. Compared to rainfed condition, It was concluded that one supplementary irrigation of Dragon's head led to 130% and 99% increase in seed and biological yield, respectively.

**Keywords:** 1000-Seed weight, biological yield, harvest index, seed yield.

# فواصل مطلوب کاشت بالنگوی شهری در شرایط دیم و آبیاری تکمیلی

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**چکیده**

**برای بررسی فواصل مطلوب کاشت برای عملکرد و اجزای عملکرد بالنگوی شهری در شرایط دیم و آبیاری تکمیلی، یک آزمایش فاکتوریل در سال ۱۳۹۳ بر پایه طرح بلوک‌های کامل تصادفی با سه تکرار در دانشگاه ارومیه انجام شد. تیمارهای آزمایش شامل فواصل کاشت (فواصل بین ردیف‌های کاشت ۱۵ و ۳۰ سانتی‌متر و فواصل بوته در روی ردیف یک و دو سانتی‌متر) و آبیاری (کشت دیم و آبیاری تکمیلی) بودند. بیشترین تعداد برگ (۱۰۵ عدد در بوته)، وزن برگ (۱۹۶۱ میلی‌گرم در بوته) و وزن گل (۲۴۲ میلی‌گرم در بوته) از ردیف‌ها (۳۰ سانتی‌متر) و فواصل بوته (۲ سانتی‌متر) عریض با آبیاری تکمیلی به‌دست آمدند. همچنین بیشترین ارتفاع بوته (۴۳/۷ سانتی‌متر) از آبیاری تکمیلی به‌دست آمد. در مقایسه میانگین‌ها، بالاترین عملکرد دانه (۲۷۳۰ کیلوگرم در هکتار) از تیمار آبیاری تکمیلی با ردیف‌های کاشت باریک‌تر (۱۵ سانتی‌متر) و فواصل دو سانتی‌متر روی ردیف به‌دست آمد. بیشترین عملکرد بیولوژیک (۴۹۳۵ کیلوگرم در هکتار) و شاخص برداشت (۵۲ درصد) نیز از آبیاری تکمیلی گیاهانی که در ردیف‌هایی با فاصله ۱۵ سانتی‌متر کاشته شده بودند، حاصل شد و آبیاری تکمیلی بیشترین وزن هزاردانه (۴/۹۶ گرم) را تولید کرد. بر اساس نتایج، انجام یک‌بار آبیاری تکمیلی در گیاه بالنگوی شهری در مقایسه با شرایط دیم، منجر به افزایش عملکرد دانه و بیولوژیک، به‌ترتیب به‌میزان ۱۳۰ و ۹۹ درصدشد.**

**واژه‌های کلیدی:** شاخص برداشت، عملکرد بیولوژیک، عملکرد دانه، وزن هزار دانه.

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## Introduction

Dragon's head (*Lallemantia iberica* L. Fisch. et Mey.) is a valuable annual medicinal herb that its leaves or seeds can be used economically. It belongs to Lamiaceae family and is distributed throughout South Western Asia and Europe (Hedrick, 1972; Ursu & Borcean, 2012). It grows well in arid zones and requires a light well-drained soil (Ion *et al.*, 2011).

Oil of *L. iberica* seeds are composed of the large fatty acids like palmitic 6.5%, stearic 1.8%, oleic 10.3%, linoleic 10.8% and linolenic 68% (Overeem *et al.*, 1999). Seed mucilage of Dragon's head acts as energy reserve and is used in the treatment of nervous, hepatic and renal diseases (Usher, 1974; Amanzadeh *et al.*, 2011). The average of seed yield is 212 to 1872 kg ha$^{-1}$. In Czech condition, Linolenic (62.27%), oleic and linoleic (10%) acids are prevailed in seeds of *Lallemantia iberica* (Strasil & Kas, 2005).

Water deficit reduces the metabolic and physiological functions of plants immediately (Din *et al.*, 2011); therefore, to achieve high yield, an adequate water supply is required during the growing season. The maximum yield and yield components are acquired by means of full irrigation during flowering and fruit formation periods as the most sensitive stage to water deficit (Blum, 2005). Plant density is one of the main factors determining seed yield. Moreover, low plant density would lead to low utilization of available soil water (Long *et al.*, 2001). It was found that, if two-thirds of the required water was available, yield would decrease by 10 of well-watered plants; however, it was reduced up to 50%–60% in rainfed condition (Oweis *et al.*, 1999). Several reports indicate the significant changes of yield and yield components in Chicory (Taheri *et al.*, 2009) and Pumpkin (Babayee *et al.*, 2012) from different planting densities.

Manipulating the micro-climate to get better crop growth resulted in optimal planting distances. A suitable distance increases the availability of nutrients, aeration and light intensity by which the potential yield can be obtained. The positive effect of planting distance on the growth, yield, and active ingredients has been reported on *Callicarpama crophylla* (Sharma *et al.*, 2004), *Curcuma aromatic* (Singh *et al.*, 2006), *Dracocephalum moldavica* (Hussein *et al.*, 2006) and *Hibiscus sabdariffa* (Ramos *et al.*, 2011). Normally, increasing plant density decreases plant height, head diameter and 1000-achne weight (Amjed *et al.*, 2013); however, the highest effective substances yield in Basil (*Ocimum basilicum* L.) was obtained from lower plant density (Arabaci & Bayram, 2004). The maximum oil percentage and yield in coriander (*Coriandrum sativum* L.) were obtained in the density of 30 plant m$^{-2}$ (Masood *et al.*, 2004). Drought affects plant growth and yield by means of membrane integrity, photosynthetic pigment content, osmotic adjustment, water relations and photosynthesis intensity (Benjamin & Nielsen, 2006; Demirevska *et al.*, 2009; Li *et al.*, 2010). Despite *L. iberica* herb is being introduced in several regions and limited agricultural practices have been conducted to explore the best production manner of this herb under arid and semi-arid regions (El-saady *et al.*, 2013). Therefore, this study was carried out to determine the influence of planting distance, irrigation and their interaction effects on dragon's head growth, herb biomass, yield and yield components under two rainfed and one supplementary irrigation conditions.

## Materials and Methods

A factorial experiment was conducted based on Randomized Complete Block Design (RCBD) with three replications at Urmia University (37° 39' N and 44 ° 58' E, altitude 1365 m, West Azarbaijan Province, Urmia, Iran) in 2014. Treatments were inter-row distance (15 and 30 cm), intra-row distance (1 and 2 cm) and irrigation (rainfed and supplementary irrigation). The soil characteristics of experimental site are presented in Table 1. The seeds were sown in depth of 2 cm on March 19, 2014. Plants were monitored carefully during growth period and weeds were controlled by hand.

Table 1- The soil characteristics of the experimental site.

| Depth (cm) | Texture | Clay | Silt (%) | Sand | pH | N (%) | P (mg kg$^{-1}$) | K (mg kg$^{-1}$) | OC* (%) | EC (dS m$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0-30 | Clay-loam | 34 | 33 | 33 | 7.6 | 0.14 | 15.3 | 402 | 1.36 | 0.84 |

*: Organic Carbon

At maturity, the middle part of each plot was harvested by a 1 m$^2$ quadrate. At harvesting time (27 June 2014), the whole plant parts were harvested to obtain the seed and biological yield. To measure the yield components, 10 plants of each experimental unit were harvested.

Leaf and flower numbers per plant, leaf and flower weights (mg plant$^{-1}$), plant height (cm) and stem diameter (mm) were measured were averaged over ten plants. The weights of 4 × 100- seed samples were measured to evaluate the1000-seed weight (g). Stem diameter was measured with caliper and harvest index (ratio of seed yield to biological yield) was calculated based on the yield obtained from 1m$^2$ harvested plants. The data were analyzed by MSTATC software and the means were compared using Duncan multiple range test at $P \leq 0.05$. The 10-year precipitation and temperature of experimental site is given in Table 2.

Table 2- Precipitation and temperature of the experimental site (10-year duration).

| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|
| Precipitation (mm) | 167.2 | 427.6 | 264.7 | 247.0 | 291.8 | 329.2 | 409.1 | 281.9 | 246.6 | 347.3 |
| Temperature (º C) | 13.67 | 13.77 | 13.43 | 13.72 | 13.57 | 15.65 | 12.83 | 14.23 | 13.73 | 14.6 |

## Results and Discussion

Analysis of variance (ANOVA) showed the significant effects of irrigation on the plant height and 1000-Seed weight ($P \leq 0.01$); and significant effects of intra-row distance on biomass yield ($P \leq 0.01$), plant height and harvest index ($P \leq 0.05$). The interaction effects of irrigation × inter-row distance on the flower number per plant, stem diameter, biomass yield ($P \leq 0.01$) and harvest index ($P \leq 0.05$) was significant. The inter-row × intra-row interaction effects on stem diameter ($P \leq 0.05$) were significant too. Also three-way interaction effects of irrigation ×inter-row× intra-row distance on the leaf number per plant, leaf weight, flower weight, and seed yield ($P \leq 0.01$) were observed (Table 3).

Table 3. Variance analysis of the effects of sowing distance and rainfed and supplementary irrigation conditions on the yield components of *Lallemantia iberica.*

| Source of Variation | df | Mean Squares | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Leaf number per plant | Flower number per plant | Plant height | Stem width | Leaf Weight | Flower weight | Biomass yield | Seed yield | Harvest index | 1000-Seed weight |
| Block | 2 | 15.705$^{ns}$ | 413.315$^{ns}$ | 6.845$^{ns}$ | 0.015$^{ns}$ | 49065.4$^{ns}$ | 946.6$^{**}$ | 70252.03$^{ns}$ | 841.8$^{ns}$ | 45.4$^{ns}$ | 0.184$^{ns}$ |
| Irrigation (A) | 1 | 980.482$^{**}$ | 43222.59$^{**}$ | 205.920$^{**}$ | 1.52$^{**}$ | 10689.3$^{ns}$ | 19412.9$^{**}$ | 30787941$^{**}$ | 9990715.0$^{**}$ | 231.1$^{*}$ | 4.472$^{**}$ |
| Row distance (B) | 1 | 2713.62$^{**}$ | 18990$^{**}$ | 38.760$^{ns}$ | 0.721$^{**}$ | 3038461.8$^{**}$ | 10293.1$^{**}$ | 411499.9$^{*}$ | 892193.6$^{**}$ | 495.7$^{**}$ | 0.018$^{ns}$ |
| Intra-row distance(C) | 1 | 63.375$^{ns}$ | 3950.1$^{*}$ | 85.503$^{*}$ | 0.416$^{**}$ | 113919.3$^{ns}$ | 3630.3$^{**}$ | 737483.9$^{**}$ | 32457.6$^{ns}$ | 278.1$^{*}$ | 0.005$^{ns}$ |
| A×B | 1 | 925.042$^{**}$ | 18210.55$^{**}$ | 0.303$^{ns}$ | 0.881$^{**}$ | 401838.8$^{*}$ | 4219.5$^{**}$ | 1390066.6$^{**}$ | 145557.7$^{*}$ | 153.7$^{*}$ | 0.011$^{ns}$ |
| A×C | 1 | 1063.50$^{**}$ | 1625.26$^{ns}$ | 8.760$^{ns}$ | 0.077$^{ns}$ | 257611.8$^{ns}$ | 5435.3$^{**}$ | 169302$^{ns}$ | 7013.7$^{ns}$ | 4.9$^{ns}$ | 0.020$^{ns}$ |
| B×C | 1 | 157.082$^{ns}$ | 3148.75$^{ns}$ | 46.760$^{ns}$ | 0.256$^{*}$ | 581103.8$^{**}$ | 4182.4$^{**}$ | 76362.22$^{ns}$ | 44197.3$^{ns}$ | 92.4$^{ns}$ | 0.052$^{ns}$ |
| A×B×C | 1 | 2031.36$^{**}$ | 300.333$^{ns}$ | 17.853$^{ns}$ | 0.0001$^{ns}$ | 798437.8$^{**}$ | 6482.1$^{**}$ | 121964.36$^{ns}$ | 173781 $^{**}$ | 5.8$^{ns}$ | 0.064$^{ns}$ |
| Error | 14 | 87.285 | 730.855 | 10.771 | 0.033 | 58599.1 | 313.1 | 60119.44 | 16844.3 | 31.8 | 0.142 |
| Coefficient of Variation (%) | | 13.98 | 20.11 | 8.06 | 5.63 | | 19.45 | 14.43 | 7.15 | 7.96 | 12.03 |

ns, * and ** ; non-significant and significant at $P \leq 0.05$ and $P \leq 0.01$, respectively. df; degree of freedom

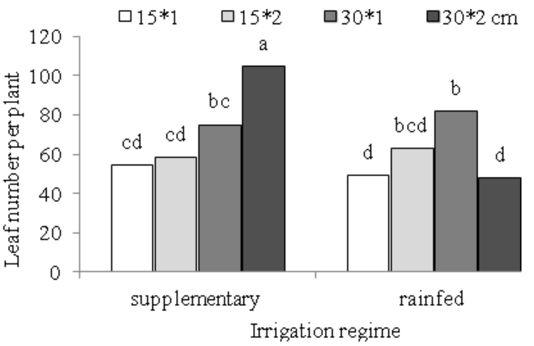
Mean comparisons indicated the highest numbers of leaves per plant (105.1) in supplementary irrigation with wide inter- (30 cm) and intra-row (2 cm) distances. In supplementary irrigation, there were increasing trends of dragon's head leaf number per plant by wide distances of inter- and intra-row. However, in rainfed condition, this increase was continued to 30×1 cm, so that 30×2 cm sowing distances showed high leaf number reductions which led to minimum numbers in mentioned treatment (Figure 1 A).

Similar to the numbers of leaf per plant, the highest weight of leaves (1813 mg plant$^{-1}$) was obtained from supplementary irrigation with wide inter- (30 cm) and intra- (2 cm) row distances. In supplementary irrigation, there were increasing trends of dragon's head leaf weight by increasing inter- and intra-row distances. However, in rainfed condition, this increase was continued to 30×1 cm, so that 30×2 cm sowing distance showed a large decrease in leaf weight 939.5 (mg plant$^{-1}$) that led to minimum weights in the mentioned treatment (Figure 1 B).

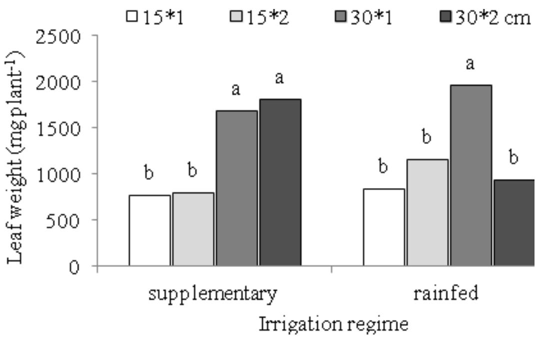
The highest weight of flowers (242 mg plant$^{-1}$) was obtained from supplementary irrigation with wide inter- (30 cm) and intra- (2 cm) row distances. In supplementary irrigation, with narrow inter- (15 cm) and wide intra- (2 cm) row distances, flower weight was reduced (114.8 mg plant$^{-1}$) and then, there were increasing trends of dragon's head flower weight by increasing inter- and intra-row distances. But in rainfed condition, all sowing distances showed an identical and large reduction in flower weight which led to minimum weights (Figure 1 C).

The maximum numbers of flower per plant (232.6) and stem diameter (3.89 mm) were obtained from 30 cm inter-row distance and supplementary irrigation (Figures 2 A , 2 B). Overall, the number of flowers per plant was higher in supplementary irrigation compared to rainfed in wide rows (Figure 2 A).

A




B




C

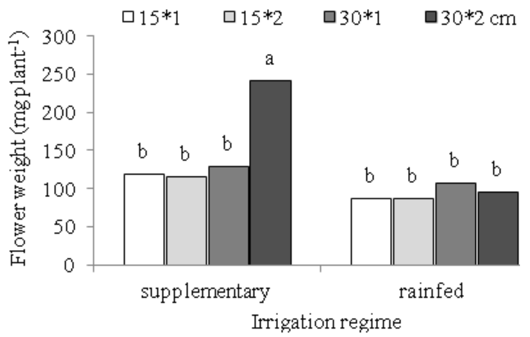



Figure 1. Means comparison of leaf number per plant (A), leaf weight (mg plant$^{-1}$) (B) and flower weight (mg plant$^{-1}$) (C) affected by inter- and intra-row distances in two irrigation regimes (Supplementary and Rainfed). Columns with the same letters in the same figure are not significantly different ($P \leq 0.05$).

Supplementary irrigation and 15 cm inter-row distance resulted in the maximum biological yield (4935 kg ha$^{-1}$). There werewere no differences between two row spacing. Totally, the biological yield was higher in supplementary irrigation compared to rainfed. In supplementary irrigation, biological yield was reduced with increasing row distances, however, it was the same for two rows distances in rainfed condition (Figure 2 C). The minimum harvest index (36.71) was observed in rainfed condition with 30 cm inter-row distance (Figure 2 D).

The plant height obtained from supplementary irrigation (43.7 cm) was significantly higher than rainfed irrigation (37.8 cm) conditions (Figure 3 A). Supplementary irrigation produced the maximum 1000-seed weight (4.9583 g) that was significantly higher than ranfied condition (4.095 g) (Figure 3 B).

The maximum stem diameter (3.682 mm) was obtained from 30×2 cm inter- and intra-row distances but the minimum stem diameter (3.072 mm) was observed in 15×1 cm inter and intra-row distances and was identical to 30×1 cm and 15×2 cm inter- and intra-row distances (Figure 4).

Means comparison of seed yield indicated that supplementary irrigation with narrow inter- (15 cm) and wide intra- (2 cm) row distances had the highest seed yield (2730 kg ha$^{-1}$). In supplementary irrigation, the seed yields obtained from 15 cm row distances were higher than 30 cm for both two intra-row distances. Seed yield in two intra-row distances (1 and 2 cm) was equal when the inter-row distance was 30 cm. The same was observed in rainfed condition; the highest seed yield (1124 kg ha$^{-1}$) was achieved in narrow inter- (15 cm) and intra- (1 cm) row distances and the lowest seed yield (809 kg ha$^{-1}$) achieved in rainfed condition with 30×1 cm planting distances, identical to 15×2 and 30×2 cm (Figure 5).

The leaf numbers increase in irrigated and widely spaced plants. The leaves of *L. iberica* are developed in pairs at each stem node (two bracts for each of the two opposite leaves), under a polynomial curve during the fully developed of the pair leaves on the main stem. The total number of leaves on the main stem was 16 on average (ranged 14 to 17). It took about 45 days after seedling for leaf numbers to reach the average. Each leaf has two bracts at its base, one on each side of the leaf (Ion *et al.*, 2011).

In the present study, the yield (biological and seed) was significantly increased in supplementary irrigation compared to rainfed condition. The grain yield and 1000-grain weight in sunflower plants were reduced as a result of increasing the drought stress (Erdem *et al.*, 2006). At the maturity stage, the *L. iberica* plant height was 40.8 cm on average (ranged 36 and 46.7 cm), and the plant biomass was 3.7 g dry matter plant$^{-1}$ (3.35 and 4.05 g dry matter plant$^{-1}$). The seeds are small, so that 1000- seed weight is 4.7 g on average (Ion *et al.*, 2011).

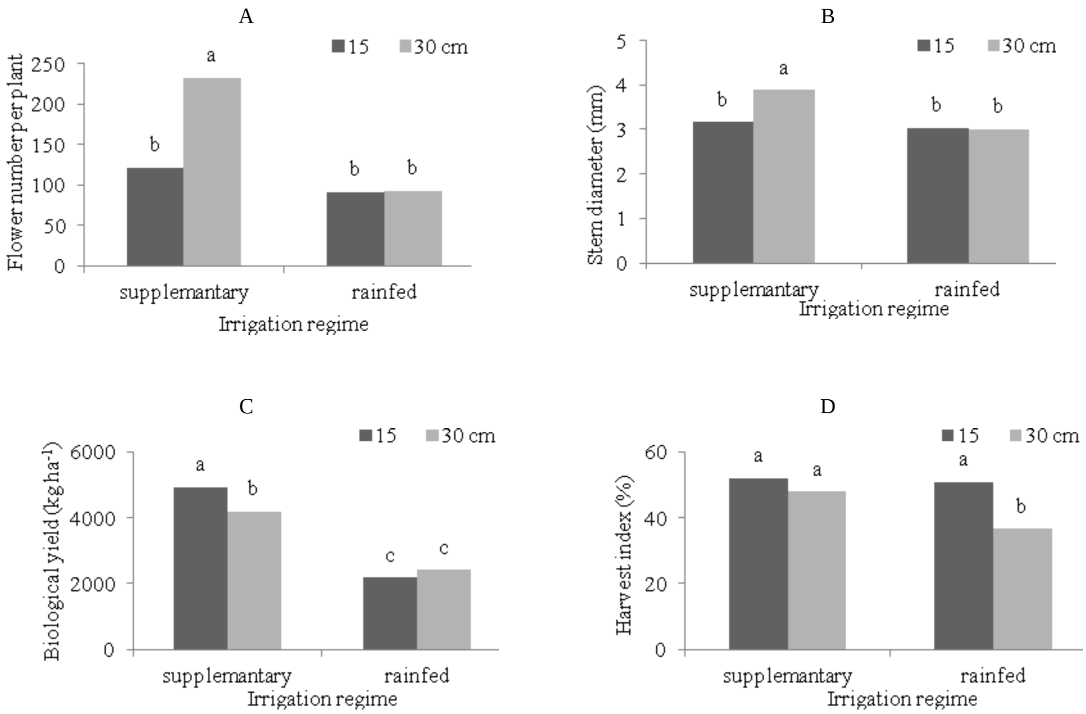



Figure 2. Means comparison of flower number per plant (A), Stem diameter (B), biological yield (C) and harvest index (D) affected by inter-row distances in two irrigation regimes (Supplementary and Rainfed). Columns with the same letters in the same figure are not significantly different ($P \leq 0.05$).

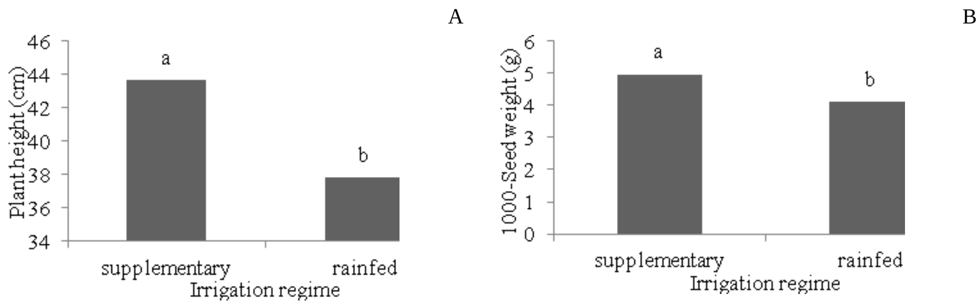



Figure 3. Means comparison of plant height (A) and 1000-seed weight (B) affected by two irrigation regimes (Supplementary and Rainfed).

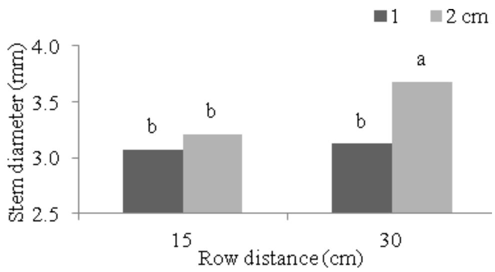



Figure 4. Means comparison of stem diameter (mm) at two inter- (15 and 30 cm) and intra- (1 and 2 cm) row distances. Columns with the same letters in the same figure are not significantly different ($P \leq 0.05$).

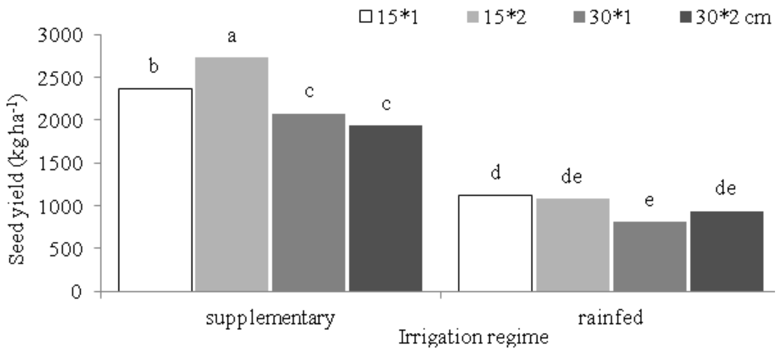



Figure 5. Means comparison of seed yield (kg ha$^{-1}$) affected by inter- and intra-row distances in two irrigation regimes (Supplementary and Rainfed). Columns with the same letters in the same figure are not significantly different ($P \leq 0.05$).

Our finding showed 21 % increase in 1000-grain weight in irrigated treatments. The high 1000-seed weight, resulting from more irrigation, was probably due to the availability of adequate soil moisture and assimilates from source to sink at seed formation and ripping stages (Nazarli *et al.*, 2010). Similar to the present study, drought stress had caused a significant reduction in some morphological traits e.g. plant height, stem weigh, and flower yield of *Matricaria chamomilla* in other studies (Razmjoo *et al.*, 2008; Baghalian *et al.*, 2011). It might be due to the decline in the cell size enlargement and more effectively reduction of turgor pressure (Shao *et al.*, 2008).

Harvest index in Dragon's head plants was higher in narrow rows planting distances which received supplementary irrigation. The changes of biological and seed yields were so varied so that the peas harvest index was increased to 14 % with the supplementary irrigation (Pezeshkpour *et al.*, 2008). The lowest harvest index for 30 cm row distances in rainfed condition was due to little amounts of seed yield. Pervious results clearly indicated that any changes in moisture in optimum condition reduce the yield of *Matricaria recutita* (Pirzad *et al.*, 2011), *Fumaria purpurea* (Omidbaigi, 1993) and *Atropa belladonna* (Baricevic *et al.*, 1999). Our findings showed the maximum harvest index in 15 cm inter-row distance in both the irrigated and rainfed plants.

In supplementary irrigation, the plant performance including biomass, seed yield and plant height was significantly higher in narrow rows; however, they were not different in rainfed condition in narrow and wide rows. The highest yield of dried flowers, essential oils and seeds of German chamomile was produced in narrow row distances which led to maximum harvest index. Therefore, the great value of biomass compared to fraction caused a converse trend of dried flower, essential oil and seed yield versus harvest index (Pirzad *et al.*, 2011). Water deficit reduces plant photosynthesis by stomata closing, leaf area decreasing, stomata gravity and protein and chlorophyll synthesis; however, reducing photosynthetic transport accumulates the products in the leaves and results in photosynthesis diminution, limiting growth and crop yield (Levitt, 1980).

## Conclusion

Significant interaction effects of inter- and intra-rows and irrigation on some plant morphological characteristics and yield (biological and seed) of *L. iberica* resulted in different responses of this plant. In this matter, the plant performance was enhanced by one-time supplementary irrigation, resulting in higher yield. This increase was more significant for biological (99 %) and seed (130 %) yields. However, varying distances for inter- and intra-row distances resulted the different performance of the plant growth. Therefore, 15×2 cm planting space produced the maximum yield of Dragon’s head seed for both rainfed and supplementary irrigation conditions. While there was no significant difference between 30 and 15 cm inter-row distances for the grain yield, it seemed that the 2 cm intra-row planting distance enhanced the plant performance in rainfed condition. Nonetheless, higher yields were obtained from wide cultivated plants in supplementary irrigation condition.

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