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**Research paper**

# Yield, yield components, and essential oil content of dragon's head (*Lallemantia iberica*) intercropped with chickpea (C*icer arietinum* l.)

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**Abstract**
Intercropping improves the efficiency of using resources such as water, nutrients, and solar radiation, which consequently increases yield per unit area. Moreover, it enhances soil fertility and plant nutrient supply. This study was conducted to evaluate the grain yield and production of dragon head essential oil under intercropping with chickpeas. The experiment was arranged in a randomized complete block design with three replications. Intercropping patterns included the pure stand of dragon's head, monoculture of two chickpea varieties (Azad, Arman), additive intercropping of the optimal density of Azad and Arman chickpea + 40%, 60%, and 80% of the optimum density of dragon's head. The highest and lowest biomass and grain yield of the dragon's head were obtained in sole cropping and 80% dragon's head + 100% Azad chickpea, respectively. Moreover, the highest essential oil content and yield of the dragon's head were obtained from the cropping pattern of 60% dragon's head + 100% Azad chickpea. Also, the land equivalent ratio (LER) was greater than one for all intercropping patterns, except for the intercropping of 80% dragon's head along with 100% Arman and Azad chickpeas, and the highest partial LER of dragon's head was obtained from intercropping of 40% dragon's head with100% Arman chickpea. In general, intercropping 40% dragon's head with100% density of both cultivars of the chickpea seems a suitable model for intercropping these two crops.

**Keywords:** dragon's head; essential oil yield; grain; yield intercropping; land equivalent ratio

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## Introduction

Intercropping is defined as the simultaneous planting of more than one species in the same place, in which the plants usually spend a significant part of their growth period concurrently (Rezaei Chiyaneh *et al.* 2019). Intercropping improves the yield per unit area (Salehi *et al*. 2018), and the efficiency of using resources such as water, nutrients, and solar radiation (Barker and Dennett 2013; Nassiri Mahallati *et al.* 2015; Wang et al., 2017). Moreover, it increases the soil fertility and supply of plant nutrients (Chen *et al.* 2019; Reza *et al.* 2019; Zhang *et al.* 2020). It may also help control weeds and reduce the effect of pests and diseases (Bedoussac *et al.* 2015).

In traditional farming in developing countries, intercropping of legumes with other plants is the most common form of cropping method (Amani Machiani *et al.* 2019). After cereals, legumes are the second most important source of protein-rich plant foods for humans (Bedoussac *et al*. 2015). As a result, legumes play an important role in ensuring the long-term viability of agricultural systems (Celmeli *et al*. 2018). In West Asia and North Africa, chickpea is one of the three most common legumes. This plant is widely cultivated almost everywhere globally, especially in semi-arid regions, and it plays an essential role in

intercropping because it conserves nitrogen in the soil (Nasrollahzadeh *et al.* 2014).

It has been reported that intercropping of medicinal and aromatic plants with legumes leads to an increase in essential oil production (Fallah *et al.* 2018; Amani Machiani *et al.* 2019). Medicinal plants such as dragon's head are useful secondary metabolites. The extracts and essential oils of dragon's head are used in cosmetics, pharmaceuticals, food, and flavoring industries (Dmitruk and Weryszko-Chmielewska 2010). It has been reported that the essential oil of this plant has antioxidant, antimicrobial, and antibacterial activities. Besides, it is used to treat prostate and breast cancer (Dastmalchi *et al.* 2007). In addition to expectorant and fungicidal properties, its mucilage seeds are used to treat neurological and liver diseases (Heidari and Pirzad 2020).

Due to the importance of the pharmaceutical and aromatic plants, different methods should be used to improve the quality and quantity of these plants, including dragon's head. The current research sought to: (i) determine the impact of chickpea cultivars on the yield and essential oil yield of dragon heads; (ii) determine the best chickpea cultivar for intercropping, and (iii) use the land equivalent ratio (LER) to evaluate intercropping compared to sole cropping.

## Materials and Methods

### *Experimental site conditions*

A field experiment was carried out at the Research Station of the Faculty of Agriculture, University of Tabriz, East Azerbaijan, Iran, in 2014. According to meteorological maps, the climate of this region is steppe and semi-arid. In summer, although it sometimes rains, generally, it has a dry climate. The average minimum, mean, and maximum annual temperatures over 10 years are 2.2, 10, and 16 °C, respectively, and the average annual rainfall is 271.3 mm. The altitude of this region is 1676 m above sea level. Also, the longitude and latitude are 45° 25' E and 31° 1' N, respectively. Based on the soil analysis of the test site, the acidity, electrical conductivity (EC), potassium, phosphorus, nitrogen, and soil texture were 7.2, 1 dS/m, 250 mg/kg, 9.5 mg/kg, 0.3%, and sandy clay, respectively.

### *Treatments and cropping conditions*

The experimental design was a randomized complete block design with three replications. The treatments included pure cropping of Dragon's head, and Azad and Arman chickpea cultivars, as well as incremental intercropping at 40, 60, and 80% ratios of Dragon's head and optimum density of Arman and Azad cultivars of chickpea. Both chickpea cultivars (Azad, Arman) seeds were prepared from the Kermanshah Research Centre, Iran. The Dragon's head seeds were obtained from Pakan Bazr Company, Isfahan, Iran. The plants were sown on 4 May 2014. The optimum densities of the chickpea and Dragon's head were 50 and 400 seeds $m^{-2}$, respectively. The size of each plot was 2 × 3 m and consisted of 10 rows. The crops were cultivated according to organic agriculture practices with no herbicide or pesticide applications. In addition, the weeds were controlled by hand weeding during the growing season.

### *Extraction of essential oil*

At the end of the flowering stage, the aerial parts of the dragon's head were harvested, dried in the shade, and powdered. 50 g of the powdered dragon head aerial parts was hydro-distilled for 3.5 h using a Clevenger apparatus (British Pharmacopoeia 1988) for evaluating the essential oil content and yield.

***Land equivalent ratio***

To evaluate intercropping of the dragon's head with chickpeas, LER was calculated using the following formula:

$$LER = (Y_1 / D_1) + (Y_2 / C_2)$$

Where $Y_1$ and $Y_2$ are pure crop yields of the two plants and $D_1$ and $C_2$ are yields of intercropping.

An LER value of more than 1.0 indicates an intercropping advantage or demonstrates that the interspecific competition is lower than interspecific facilitation, meaning that intercropping resulted in greater land-use efficiency. The LER value of 1.0 indicates that the two intercropped species make similar demands on the same limited resources. Also, the LER value lower than 1.0 means mutual antagonism in the intercropping system. Thus, the LER value of less than 1.0 indicates no intercropping advantage and reveals that interspecific competition is higher than interspecific facilitation in the intercropping system (Fetene 2003; Wahla *et al.* 2009).

***Statistical analysis***

Analysis of variance was performed as a randomized complete block design using MSTAT-C software. The treatment means were compared using Duncan's multiple range test at the 5% probability level.

**Results and Discussion**

***Grain yield***

The effect of different planting patterns on the grain yield was significant (Table 1). The highest grain yield was related to dragon's head sole cropping, and the lowest grain yield was observed in the intercropping pattern of 80% dragon's head + 100% Azad chickpea without significant difference with the planting pattern of 80% dragon's head + 100% Arman chickpea (Figure 1). Rohi-Saralan *et al.* (2018) on intercropping of the dragon's head with purslane reported a reduction in the grain yield in the intercropping treatments compared with the sole cropping. According to Nasrollahzadeh *et al.* (2014), in the intercropping of the chickpea and dragon's head, the grain yield of the dragon's head in the sole cropping was higher than intercropping, which seems to result from increased competition in the intercropping conditions and reduced environmental resources. In a study of intercropping mung bean with maize, the yield of mung bean was lower than its sole cropping (Pandita *et al.* 2000).

***Harvest index***

Analysis of variance for dragon's head harvest index (Table 1) showed that different intercropping patterns significantly affected the harvest index. The highest harvest index was obtained from the pure stand of the dragon's head, however, it was not significantly different from the intercropping pattern of 40% dragon's head + 100% of Arman and Azad chickpeas. The lowest harvest index belonged to the treatment of 80% dragon's head + 100% of Arman and Azad chickpeas (Figure 2). In a study of different intercropping patterns of

Table 1. Analysis of variance of dragon's head affected by intercropping patterns with chickpeas

| SOV | df | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | Grain yield | Harvest index | Biomass | 1000 grains weight | Essential oil content | Essential oil yield |
| Block | 2 | 191.29$^{**}$ | 24.03 | 1137.90$^{**}$ | 27.24 | 0.002 | 0.019 |
| Intercropping patterns | 6 | 1001.15$^{**}$ | 80.96$^{*}$ | 597.98$^{**}$ | 30.40$^{ns}$ | 0.56$^{**}$ | 3.80$^{**}$ |
| Error | 12 | 15.06 | 6.94 | 94.59 | 23.99 | 0.001 | 0.039 |
| CV (%) | - | 3.09 | 4.73 | 4.32 | 27.41 | 5.86 | 3.12 |

* and **: Significant at 5 and 1% probability levels, respectively

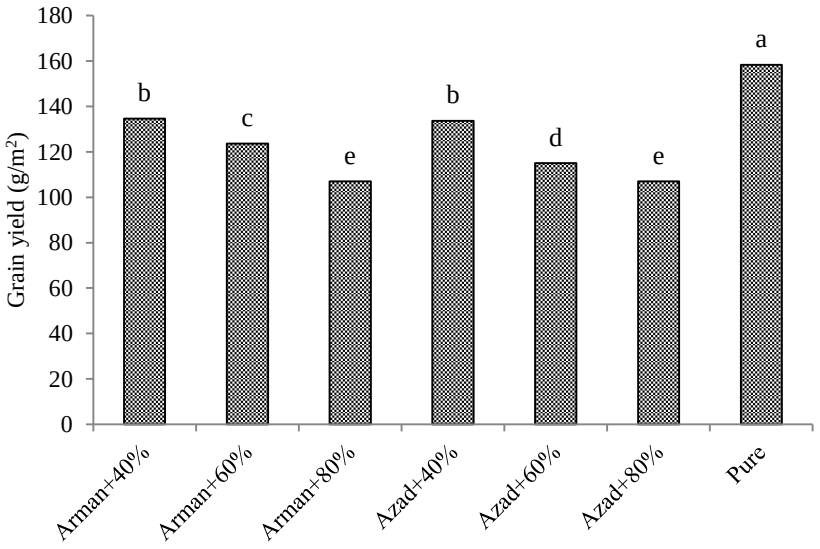


Figure 1. Effect of different intercropping patterns of dragon's head with chickpeas on its grain yield.

mungbean, Bismillah Khan and AbdulKhaliq (2004) reported the highest harvest index for the sole cropping of mungbean. In grain crops, the harvest index can be affected by environmental conditions, and sole cropping eliminates interspecific competition. Therefore, the plant can use more light and available resources and increase its economic yield (Neugschwandtner and Kaul 2014).

***Biomass***

The biomass of the dragon's head was significantly affected by different planting patterns (Table 1). The highest biomass of the dragon's head was observed in the sole cropping of the dragon' s head, and the lowest biomass was detected in the intercropping of 80% dragon's head + 100% Azad chickpea (Figure 3). In intercropping of barley and alfalfa, the biomass of barley declined by 6-62% (Ledgard 1991). Most researchers have attributed

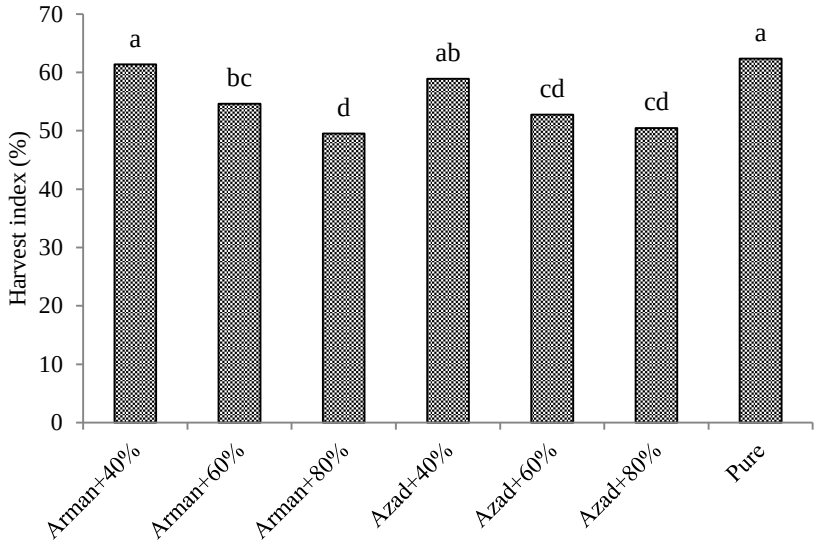


Figure 2. Effect of different intercropping patterns of dragon's head with chickpeas on its harvest index.

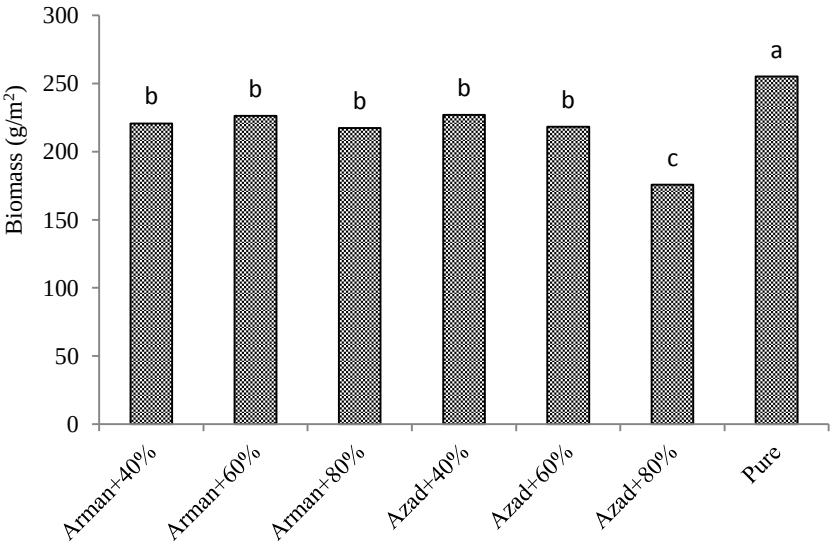


Figure 3. Effect of different intercropping patterns of dragon's head with chickpeas on its biomass.

the reduction in biomass in intercropping due to competition for the uptake of resources such as light, water, nutrients, and space of the two crops or species (Zhang *et al.* 2008).

***1000-grain weight***

The results of the analysis of variance showed that there was no significant difference among treatments for 1000-grain weight (Table 1). Kumar *et al.* (2009) also reported that different intercropping ratios did not affect the grain weight. The highest and the lowest 1000-grain weight of

the dragon's head was related to the sole cropping and intercropping of 80% dragon's head + 100% Arman chickpea, respectively, however, as mentioned above, it was not different significantly from the other treatments.

***Essential oil content***

The effect of different intercropping treatments on the content of essential oil was significant (Table 1). The highest essential oil content was related to the intercropping of 60% dragon's head + 100% of Azad chickpea, which was placed in a statistical group with the same treatment in Arman chickpea. Additionally, the lowest content of essential oil was related to the sole cropping of the dragon's head, which was not significantly different from the combination of 40% dragon's head + 100% Azad chickpea (Figure 4). Maffei and Mucciarelli (2003) reported that in the intercropping of peppermint and soybean, the essential oil of peppermint increased by up to 50% in the intercropping treatments. In another study, the essential oil content of fennel in the intercropping with beans was higher than its sole cropping (Rezaei Chianeh *et al.* 2019). Proper vegetative growth with sufficient stress is a reason for high essential oil content under relatively severe stress.

***Essential oil yield***

The effect of different intercropping treatments on the essential oil yield of the dragon's head was significant (Table 1). The highest yield of the essential oil (2.76 g/plant) was related to the intercropping treatment of 60% dragon's head + 100% of Azad chickpea, however, it was not significantly different from the intercropping treatment of 60% dragon's head + 100% of Arman chickpea. The lowest essential oil yield belonged to the pure stand of the dragon's head and the combination of 80% dragon's head + 100% of Arman and Azad chickpea cultivars. This behavior is probably due to the reduction in the plant weight at the higher plant density of the dragon's head (Figure 5). Fallah *et al.* (2018) reported that intercropping had no significant effect on the essential oil yield of the dragon's head in the intercropping with soybean. However, Weisany *et al.* (2015) indicated that intercropping with the common bean increased the essential oil yield of the dill plant.

**Land equivalent ratio**

LER is an important criterion to judge the advantage of intercropping. Table 2 shows the LER of different intercropping treatments. The highest partial LER of chickpea was obtained from the intercropping of 40% dragon's head + 100% of the Azad chickpea cultivar and the highest partial LER of dragon's head was obtained from the 40:100% intercropping combination of the dragon's head and the Arman chickpea cultivar. The chickpea's partial LER was higher than the partial LER of the dragon's head in all intercropping treatments. It can be stated that the chickpea plant had a greater effect as the accompaniment of the dragon's head, which further improved its partial LER compared to the dragon's head. All intercropping treatments, except the combination of 80% dragon's head + 100% of Azad and Arman chickpea had higher LER than the sole cropping of both plants. The highest LER

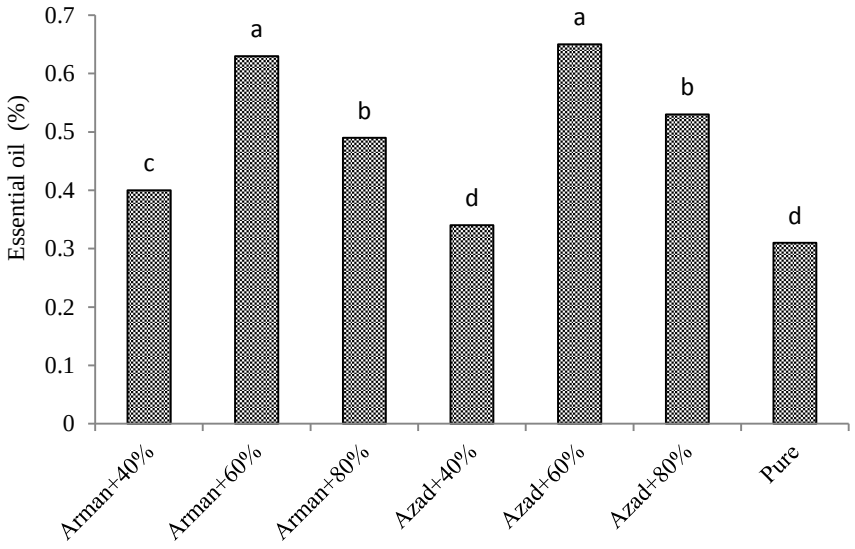


Figure 4. Effect of different intercropping patterns of dragon's head with chickpeas on its essential oil content.

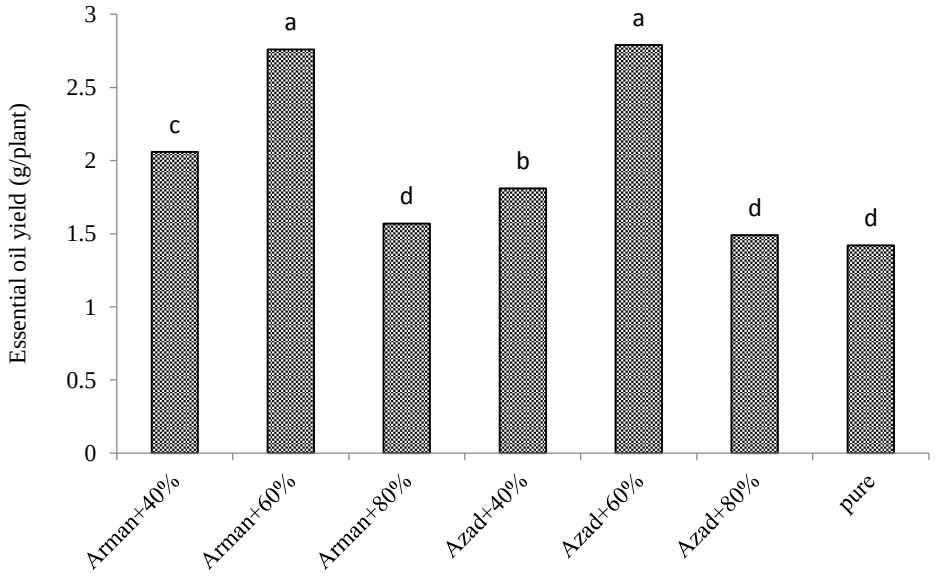


Figure 5. Effect of different intercropping patterns of dragon's head with chickpeas on its essential oil yield.

belonged to the combination of 40% dragon's head + 100% of the Azad cultivar of chickpea. The lowest LER was for the intercropping treatment of 80% dragon's head + 100% Arman chickpea, which was due to the competition of chickpea and dragon's head in the use of light and available resources (Table 2). Intercropping is beneficial when intercropping grain yield is higher than the

maximum single crop yield. In the intercropping of soybean and dragon's head, Fallah *et al.* (2018) reported that LER was more than 1 at different intercropping ratios. According to Ghosh *et al.* (2006), LER is a correct measure of assessing the efficiency of using resources such as radiation, nutrients, and rainfall. When LER is greater than one, it means that there is a benefit in intercropping, indicating that interspecific facilitation has outpaced the interspecific competition.

Table 2. Land equivalent ratios (LER) in different intercropping patterns of dragon's head with chickpeas

| Intercropping pattern | $LER_{Dragon's\ head}$ | $LER_{Chickpea}$ | $LER_{Total}$ |
|---|---|---|---|
| Dragon's head: Arman 40:100 | 0.74 | 0.76 | 1.5 |
| Dragon's head: Arman 60:100 | 0.55 | 0.60 | 1.15 |
| Dragon's head: Arman 80:100 | 0.42 | 0.43 | 0.85 |
| Dragon's head: Azad 40:100 | 0.72 | 0.82 | 1.54 |
| Dragon's head: Azad 60:100 | 0.66 | 0.71 | 1.37 |
| Dragon's head: Azad 80:100 | 0.40 | 0.45 | 0.85 |

## Conclusions

Increasing the plant density of the dragon's head in intercropping with both cultivars of chickpeas, reduced 1000-grains weight, biomass, grain yield, and the harvest index of the dragon's head. In other words, the sole cropping of the dragon's head had the highest yield, but the essential oil yield of the dragon's head was highest when intercropped with both cultivars of chickpea at 60% plant density. However, LER in the majority of the intercropping treatments was higher than one, indicating the usefulness of intercropping, and intercropping with 40% of the optimum density of the dragon's head and 100% density of the chickpeas had the highest LER.

## Conflict of interest

The authors declare that they have no conflict of interest with any organization concerning the subject of the manuscript.

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# عملکرد، اجزای عملکرد و میزان اسانس بالنگوی شهری (*Lallemantia iberica*) در کشت مخلوط با نخود

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**چکیده**

کشت مخلوط باعث افزایش عملکرد در واحد سطح، کارایی استفاده از منابعی مانند آب، مواد مغذی و تشعشعات خورشیدی، حاصلخیزی خاک و تامین مواد مغذی گیاه می‌شود. این مطالعه به منظور بررسی عملکرد دانه و تولید اسانس بالنگوی شهری، تحت تأثیر کشت مخلوط با نخود انجام شد. آزمایش در قالب طرح بلوک‌های کامل تصادفی با سه تکرار اجرا شد. الگوهای کشت مخلوط شامل کشت خالص بالنگوی شهری، کشت خالص دو رقم نخود (آزاد، آرمان)، کشت مخلوط افزایشی با تراکم مطلوب نخود آزاد و آرمان + ۴۰، ۶۰ و ۸۰ درصد تراکم مطلوب بالنگوی شهری بود. نتایج نشان داد که بیشترین و کمترین بیوماس و عملکرد دانه بالنگوی شهری به ترتیب در تیمار کشت خالص و ۸۰ درصد بالنگوی شهری + ۱۰۰ درصد نخود آزاد به دست آمد. همچنین بیشترین میزان اسانس و عملکرد بالنگوی شهری از الگوی کشت ۶۰ درصد بالنگوی شهری + ۱۰۰ درصد نخود آزاد به دست آمد. افزون بر این، نسبت برابری زمین (LER)، به جز در کشت مخلوط ۸۰ درصد بالنگوی شهری به همراه ۱۰۰ درصد نخود آرمان و آزاد، از یک بیشتر بود و بیشترین LER جزء بالنگوی شهری از کشت مخلوط ٪۱۰۰:۴۰ بالنگوی شهری و نخود آرمان به دست آمد. به طور کلی با توجه به یافته‌های این مطالعه، کشت مخلوط ٪۱۰۰:۴۰ بالنگوی شهری و تراکم مطلوب هر دو رقم نخود مدل مناسبی برای کشت مخلوط این دو گیاه می‌باشد.

**واژه‌های کلیدی**: بالنگوی شهری؛ عملکرد اسانس؛ عملکرد دانه؛ کشت مخلوط؛ نسبت برابری زمین