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Investigating the effects of urea, Azocompost and cutting on quantitative and qualitative characteristics of Oregano (Origanum vulgare virid)

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ABSTRACT
In order to investigate the effect of urea, Azocompost and cutting on growth characteristics of Oregano, a factorial split-plot experiment was conducted based on randomized complete block design with three replications at Yazd and Mashhad, Iran, during 2012-2013 growing season. Four urea levels and four Azocompost levels (to provide 0, 40, 80 and 120 kg N.ha-1 each) for Yazd location (0, 43.5, 130.4 and 217.4 kg Urea.ha-1 and 0, 4.4, 13.3 and 22.0 ton Azocompost.ha-1) and for Mashhad location (0, 21.7, 108.7 and 195.7 kg Urea.ha-1 and 0, 2.2, 11.1 and 20 ton Azocompost.ha-1) were considered as the main factors and harvesting time as the sub factor. In the present study, some growth traits, yield, yield components were measured. The results of combined analysis showed that two-way interaction between urea and Azocompost was significant for all traits except for essential oil content ($p<0.05$). Plants treated with n1a2 (Plants treated with 40 kg chemical fertilizer ha-1 and 80 kg Azocompost ha-1) and control treatments had the highest and lowest values of all traits except plant nitrogen percentage, respectively. With increasing Azocompost levels from 0 to 120 kg N ha-1, economic yield increase was 1114 kg ha-1, while increasing the levels of chemical urea fertilizer from 0 to 120 kg ha-1 increased the economic yield about 790 kg ha-1. It seems that use of Azocompost is an excellent approach to decreasing the costs that are associated with the use of urea.

Key words: Essential oil, Harvesting time, Medical plants, Nitrogen.

Introduction

Today, medical herbs are plants of economic importance which are used in raw or processed form in traditional and modern medicine (Salami et al. 2006). Wild marjoram (Origanum vulgare L.) member of the family Lamiaceae is one of the perennial and valuable medical plants in Iran. Because of commercial and high value, the exportation of these plants to all over the world is economical and of great importance (Van Wyk and Wink 2004). Wild marjoram as a plant used in traditional medicine and also as an effective medicinal plant has been recorded in the world's valid Pharmacopoeia (Van Wyk and Wink 2004).

Although the active ingredients are mainly made by genetic processes, but their synthesis is significantly influenced by climatic and environmental factors, so that the environmental factors cause changes in the growth of medicinal herbs, also the quantity and quality of their active ingredients (Omidbaigi 1997, Salami et al. 2006).

Regardless of the economic value of medicinal herbs, these plants are compatible with organic farming methods accompanied by the tendency of producers and consumers (Mirjalili 2001). Optimal use of nitrogen resources is imperative for improving economic performance and reducing environmental pollution (Mostaphi Rad et al. 2010). Nitrogen plays an important role in creating optimal qualitative and quantative yield of the plants; however this element is easily leached from the soil and results in contamination of water and reduction of nitrogen usage efficiency (Ameri et al. 2007).

Organic fertilizers like Azocompost as a nitrogen resource will improve food resources, prevent leaching of nutrients by water, and help to the plant nutrition (Mostaphi Rad et al. 2010). Azocompost is a mixture of organic materials, including Azolla plant (known as a troublesome plant in Anzali pond and paddy fields of northern Iran for a long time) and rice straw processed by microorganisms in a warm, moist, and well ventilated medium and puts its materials and nutrients in the soil as absorbable matters available for the plants (Farahdahr et al. 2011). Determination and analyzing the level of nitrogen in various tissues and organs of medicinal herbs, especially in variable environments are the most important determinant factors for optimizing the management of nitrogen in the field, the reason of the more importance of this issue in medicinal herbs is because of the profound effect of nitrogen on the essential oils of these plants (Dadvand Sarab et al. 2008). Azizi et al. (2009) with application of different levels of nitrogen on O. vulgare populations in greenhouse has reported that nitrogen application level (1.5g pot-1) increased plant dry matter, whereas it decreased the amount of essential oil. Sotiropoulou and Karamanos (2010) with Study of four nitrogen levels 0, 40, 80 and 120 kg ha-1 showed that nitrogen application significantly affected the herbage yield of O. vulgare and the amount of 80 kg N ha-1 caused the optimal plant growth. Gharib et al. (2008) by studying the effects of compost and biofertilizers on O majorana in the greenhouse, they showed that the plant growth, compositions of essential oil and plant dry matter yield with the application of organic fertilizers showed superiority over the control treatment. Koocheki et al. (2008) showed that the application of organic fertilizers has an effective and useful role in improving the growth characteristics, herbage yield and qualitative traits of hyssop (Hyssopus officinalis).

Tahmasebi Sarvestani and Mostafavi Rad (2011) in a study by application of nitrogen sources including 50% Azocompost, 50% Azocompost +50% urea and urea on varieties of oilseed rape (Brassica napus L.), they reported increased quality of oilseed rape seeds oil treated with Azocompost. Yousefzadeh et al. (2013) by using nitrogen sources of 100% urea, 75% urea +25% Azocompost, 50% urea + 50% Azocompost, 25% urea +75% Azocompost and 100% Azocompost on dragonhead (Dracocephalum moldavica L.), they reported that optimum yield and essential oil was achieved by treatment with 50% Azocompost +50% urea.

Given that climatic and environmental factors have a major influence in the growth, development and amounts of essential oils of medicinal herbs (Hassani 2006), recognizing the optimum conditions in reducing the use of harmful chemical compounds for optimal growth of wild majoram and identification of effective factors in its qualitative and quantitative changes, while reducing production costs can lead to increased revenues of producers and is an important step towards satisfying the needs of national pharmaceutical industry in the field of active pharmaceutical compositions.

Materials and Methods

Field experiments were carried out at the field research station of the Faculty of Agriculture of Ferdowsi University of Mashhad, located on 10 km East of Mashhad (36°16' N, 59°36' E and 985 m above sea level) and studies of Yazd location at the village of Darberaz, Khezrabad city located on 37 kilometers West of Yazd (31°50' N, 53° 59' E and 1830 m above sea level). In order to investigate the effect of urea, Azocompost and harvesting time on growth characteristics of wild marjoram, a factorial split-plot experiment was conducted based on randomized complete block design with three replications at Yazd and Mashhad, Iran, during 2012-2013 growing season. The result of UNEP aridity index showd that, Yazd and Mashhad were in hyperarid and semiarid condition, respectively (Ashraf et al. 2014). Climate data for the growing seasons at both sites are provided in Table 1. The soils are classified as a sandy loam and silt loam for Yazd and Mashhad experimental locations, respectively.

According to the characteristics of soil and Azocompost fertilizer (Tables 2 and 3) four urea levels and four Azocompost levels (to provide 0, 40, 80 and 120 kg N ha-1 each) for Yazd location (0, 43.5, 130.4 and 217.4 kg Urea ha-1 and 0, 4.4, 13.3 and 22.0 ton Azocompost ha-1) and for Mashhad location (0, 21.7, 108.7 and 195.7 kg Urea ha-1 and 0, 2.2, 11.1 and 20 ton Azocompost ha-1) were considered as the main factors and harvesting time as the sub factor. Azocompost was provided from Salem Saze Mohite Gil Research Production Company, (Gilan, Iran).

Marjoram planting was carried out by vegetative propagation. Four-year-old Marjoram plants were prepared from a cloning unit in the village of Darberaz in Yazd province. After adjustment of temperature for Yazd and Mashhad regions on April 5th and 6th 2013 respectively, divided marjoram plants were transferred to the main field spaced 50 cm between the rows and 20 cm on the rows where they were planted with the furrows and ridges method within each experimental (2 × 5 m) plot which was fallow during the last year. One day before planting, all the Azocompost and one third of urea fertilizer were added to the soil and the remaining two-thirds of N fertilizer was added at the beginning of stemming. The first irrigation was carried out immediately after planting and subsequent irrigations were carried out to the end of growing season once a week. In half of each experimental plot (2 × 2.5 m) five plants were selected randomly and their traits such as Plant height, canopy area, number of lateral branches/plant, number of flowers/plant, dry weight of leaves and flowers were measured. After the first cutting for Yazd and Mashhad on July 9th and 14th respectively and the second cutting for Yazd and Mashhad on October 5th and 9th 2013 at the time of maximum flowering, the aerial parts were transferred to the lab to determine the essential oil content. Using Clevenger-type apparatus, the essential oil of samples was extracted by hydro-distillation of 40 gr dried leaves and flowers of Origanum vulgare virid. This method for the extraction of oils is recommended by the European Pharmacopoeia (1983).

Economic yield was calculated per unit area and essential oil yield was calculated by multiplying the yield by essential oil percentage. The amount of nitrogen in leaves and flowers of the plant was determined using 0.3 gr of dried leaves and flowers with micro kjeldahl method.

Drawing graphs and analysis of variance were performed using Sigma Plot Ver. 12 and SAS Ver. 9.2 softwares based on Duncan’s multiple range test at the 5% significance level.

Results and discussion

In order to detect uniformity of error variance in two regions, Bartlett's test was used. According to uniform variance of errors in the experiment, combined analysis was performed for all the characteristics of the two locations.

The results of main effects indicated that except for main effects urea fertilizer on percentage of essetial oil, Azocompost fertilizer on harvest index and cutting on percentage of nitrogen, other measured traits of marjoram plant were significantly different (0.01, $p < 0.05$) (Tables 4 and 5). Two-way interaction of urea×azocompost for all traits, except for percentage of essetial oil was significant and three-way interaction on most measured characteristic were significant (Tables 4 and 5).

Interactions of urea × azocompost

When the F test in variance analysis table of a trait was not significant (Tables 4 and 5), comparison of mean was shown without significant letters. Interactions of urea × azocompost indicate that in all measured characteristics of marjoram plants except for percentage of nitrogen, the treated plants with n1a2 and control plants having a maximum and minimum significant difference, respectively (Table 6 and 7). It seems quantitative characteristics are improved by combining organic and chemically fertilizers, Due to use the azocompost fertilizer effective in improving soil conditions, higher humidity and adequately maintained to avoid leaching of nutrients and nitrogen, increased plant growth characteristics (Yousefzadeh et al. 2013).

Single increase levels of urea and azocompost fertilizer from zero to 120 kg per hectare; lead to increase 47 and 58% of plant height, respectively. Therefore, application of Azocompost alone had better results than urea fertilizer with 11% difference (Table 6). N1a2 treated plants had a 10cm more canopy area than the control treatment plants and with a significant difference they had the highest and lowest canopy area, respectively (Table 6). In terms of the number of lateral branches and number of flowers per treated plants, n1a2 and n1a3 had the maximum values and the control treatment had the least significant effect (Table 6). Since the application of fertilizer caused increased morphological traits such as plant height and number of lateral flowering branches, consequently the number of flowers increased per plant, and finally led to increased flower yields per unit area. The results of study Fariborzi (1999) on Chamomile (Matricaria chamomilla L.) showed that N fertilizer application had significant effect on chamomile yield at 5% level and the maximum dry weight of flowers was achieved by application of 100 kg N ha-1 and the minimum weight of dry flowers was achieved in the treatment without nitrogen fertilizer.

According to this study, Khandan (2005) showed that the use of organic compost fertilizer had better and more significant results on the quantitative properties of Isabgol (Plantago ovate L.) than treatment with chemical fertilizers. Hendawy (2008) showed that in medicinal plant of Plantago arenaria, the combined application of chemical fertilizers (NPK) and compost produced the highest number of flowering branches. Apparently the use of organic fertilizers due to increased humus and organic matters of soil, vitamins, hormones, and botanic enzymes which are not present in chemical fertilizers, can increase them in soil and thus increases the yield quantity (Alam 2004).

In terms of total dry weight, dry weight of leaves and flowers, plants treated with n1a2 had 61, 66 and 71% significant difference respectively compared to non-application of fertilizers treatment (Table 6 and 7). Sotiropoulou and Karamanos (2010) with the study of four nitrogen levels of 0, 40, 80 and 120 kg ha-1, according to this study results showed that nitrogen application significantly affected the O. vulgare herbag yield. Mahfouz and Sharaf-Eldin (2007) showed that the application of biofertilizers in combination with chemical fertilizers increased quantitative characteristics in the medicinal herb of Foeniculum vulgare compared to chemical control group. In another study the effect of organic fertilizers on the growth and yield of the Origanum majorana was surveyed, the results showed that biofertilizers increased the stem length, root weight, number of leaves, number of nodes and root dry weight compared to the control (no fertilizer) treatment and the reason of increased growth was suggested to be the improvement of the soil physical conditions (Banchio et al. 2008). It seems in this research also by improvement of the soil properties and preventing leaching of urea fertilizer, the Azocompost organic fertilizer improved quantitative characteristics of Wild Marjoram plant.

Nitrogen application increases the vegetative growth and increases dry matter accumulation in plants. As is clear from the results, the interaction effect of n1a2 with a yield of 1604 kg ha-1 had more economic yield than the control treatment plants with the most significant impact (Table 7). With increasing Azocompost levels from 0 to 120 kg N ha-1, economic yield increase was 1114 kg ha-1, while increasing the levels of chemical urea fertilizer from 0 to 120 kg ha-1 increased the economic yield about 790 kg ha-

1 (Table 7). Therefore, increasing Azocompost organic fertilizer to the level of 120 kg ha-1 with a 10% difference compared to the same level of urea fertilizer had greater effect on increasing the yield.
Yousefzadeh et al. (2013) with applying nitrogen resources of 100% urea, 75% urea +25% Azocompost , +50% urea + 50% Azocompost , 25% urea +75% Azocompost and 100% Azocompost on dragonhead, reported that the optimum yield was achieved in plants treated with 50% urea +50% Azocompost. In another experiment Tahmasebi Sarvestani and Mostafavi Rad (2011) reported that the effect of combined nutrition treatment by Azocompost and urea on rapeseed yield had superiority over the other treatments. Since N fertilizer increases plant photosynthesis and thereby the stored carbohydrates in plants, the use of these fertilizers increases the plant yield (Franz 1983). It seems that the decreased yield is due to using high amounts of pure N ha-1 caused by potential mineral stress (Alizadeh Sahzabi et al. 2007).
Plants treated with n1a2 significantly had the highest harvest index compared to the other treatments (Table 7). Plants treated with n1a2 and n1a3 had the highest essential oil yield in comparison with the other treatments (Table 7). Dadkhah et al. (2012) using the different levels of nitrogen fertilizer on the chamomile (Matricaria recutita) reported that chamomile essential oil yield per unit area became significant under the influence of fertilizer levels. They reported the highest essential oil yield in the third nitrogen fertilizer level (200 kg urea ha-1) with 1.01 g m-2 and the lowest was related to the treatment without using fertilizer with 0.59 g m-2. Rajeswara (2001) reported that application of 15 tons of organic fertilizer on rainfed palmorosa (Cymbopogon citrates) increased aerial parts and essential oil 10.7 and 10.3 respectively compared to the control group. He stated that improvement of water holding capacity and nutrient supply by fertilizers are the reasons of increased aerial parts yields and essential oil of this plant. He also reported that the most herbage yield and essential oil were achieved by combined application of 15 ton manure fertilizer ha-1 and 80 kg N fertilizer ha-1. Using nitrogen sources of 50% urea +50% Azocompost on dragonhead produced the optimum essential oil (Yousefzadeh et al. 2013). Nitrogen of plants treated with n2a2 was the greatest followed by n3a3 and n3a0 and the control treatment along with treatments without urea (n0a1, n0a2 and n0a3) had the lowest effect on the amount of nitrogen in leaves and flowers of wild marjoram (Table 7). Given that nitrogen is one of the most effective elements in increasing the percentage of plant’s nitrogen, it seems that increasing the use of nitrogen fertilizer has increased the accumulation of this element in the aerial parts and this situation leads to improvement of nitrogen percentage in leaves and flowers of the plants.

Interactions of urea × harvesting time

Two-way interaction between urea and harvesting time showed that except the height and percentage of essential oil, other measured plant characteristics had significant differences in the two harvests (Table 8). Overall, in the second harvesting time, all growth parameters and dry weight of aerial parts and herbage yield were more than the first harvesting time. Since wild marjoram is a perennial plant, the establishment is more of concern in the first harvesting time and from the second harvesting time when plants are stabilized, due to the full establishment of the plant and access to the soil nutrients and elements, an increased trend is seen growth characteristics and yields, in fact the plant’s energy in the first harvesting time is mainly spent on crop establishment and economic and acceptable yield of the plant is considered from the second harvesting time.
Among plants, those treated with n1h1 and n1h2 had the highest heights and there were not significant differences between the other treatments (Table 8). The canopy area of treated plants with n1h2, n2h2 and n3h2 were significantly higher than the other treatments. Increased canopy area from the first to the second harvesting time for the control treatments was 84% and for n1, n2 and n3 treatments was 80, 85 and 78%, respectively (Table 8). Thus increasing canopy area of the plant from the first harvesting time to the second one, corresponding to control treatment has also been prevalent in other treatments. The increase of canopy area of plant, lateral branches and the number of flowers per plant were similar for all

treatments from the first harvesting time to the second one, and it seems that the application of urea fertilizer in the first harvesting time has led to increased plant tillering capability and the influence of urea fertilizer was more obvious in the first harvest. N1h2 treatment effect on the dry weight traits of the total dry matter, dry weight of flowers and leaves and economic yield were significantly different than the other treatments. N1h2 treatment had the highest essential oil yield of 86.66 kg ha-1 compared to both harvesting times treatments (Table 8).

Except n3 treatment which had a significant difference in the two harvesting time, in other treatments no significant difference was observed between the two harvesting time in terms of plant nitrogen percentage (Table 8). By increasing the amounts of N fertilizer from 0 to 120 kg ha-1, the nitrogen percentage had an increasing trend equal to %1 (Table 8). Given that nitrogen is one of the most important elements in increasing the nitrogen percentage of plant, apparently increased use of nitrogen fertilizer has increased the accumulation of this element in the aerial parts of the plant, and this has led to an increase in the percentage of nitrogen.

Interactions of azocompost × harvesting time

According to Table 9, except height, canopy area and harvest index, in other measured plant characteristics, the two-way interaction of Azocompost in harvesting time had a significant difference in the two cutting. In terms of the number of flowers per plant and total dry weight in both cuttings, the control treatment significantly had the lowest number of flowers and total dry weight among the other treatments (Table 9). In the first harvesting time no significant difference was observed between treatments for the dry weight of flower, but in the second harvesting time, a2 treatment had the most amount and had an increase of 1660 kg ha-1 compared to a2 treatment of the first harvesting time, but in a0, a1 and a3 treatments, the increases from the first harvesting time to the second one were 1325, 1541 and 1633 kg ha-1, respectively (Table 9). In terms of the effect on leaf dry weight and economic yield, treatment of 80 kg Azocompost ha-1 had more significant difference than other treatments (Table 9). N2h2 and a3h2 treatments had the highest essential oil yield than other treatments which increased 55 and 58 kg ha-1 compared to the first harvesting time, respectively (Table 9). Treated control plants had the lowest essential oil yield in both cuttings and the increase of yield from first harvesting time to the second one was 45 kg ha-1 (Table 9). Increasing Azocompost level had no significant difference in increasing the plant nitrogen percentage and the difference between the two cuttings was not significant and only the treatments of 40 and 80 kg ha-1 pure organic nitrogen in the second harvesting time were significantly different (Table 9).

Interactions of urea × azocompost × harvesting time

Interactive effects of urea × Azocompost × harvesting time except the plant height, canopy area, and essential oil percentage were significant for all growth traits and yield ($P<0.05$ and 0.01) (Table 8 and 9).

Totally, the growth parameters and dry weight of aerial parts and yield of plant in second harvesting time was more than the first harvesting time. In fact, in the first harvesting time, the energy of plant is mostly spent on crop establishment and since the second harvesting time, economic and acceptable yield of the plant begins.

Plants treated with n1a2h2 and n1a3h2 had the maximum and n0a0h1 plants had the minimum number of lateral branches, number of flowers per plant and flower dry weigh (Table 8). Plants treated with n1a2 and control in both cuttings had the highest and lowest leaf dry weight, respectively so that increase of leaves weight in plants treated with n1a2 and control from the first cutting to the second cutting were 1913 and 1119 kg ha-1 (Table 9). The highest economic yield of the two sets of cuttings was related to n1a2h2 which had 68% more yield (2378.47 kg ha-1) than the lowest amount in the second cutting i.e.

control treatment. In the first harvesting time, n1a2 treatment was also higher than the control treatment with a 70% difference (829.84 kg ha-1) (Table 9).

In terms of essential oil yield, plants treated with n1a2 and n1a3 in both cuttings were significantly higher compared to the other treatments. And Control treatment in both cutting caused the lowest essential oil yield (Table 9). The results of combined use of organic and chemical fertilizers in many farming have been evaluated as positive (Tahmasebi Sarvestani and Mostafavi Rad 2011). Apparently, in this research because of Azocompost benefits in improving soil conditions, increased humidity holding capacity and providing adequate nutrients and preventing urea fertilizer leaching, the combination of organic and chemical fertilizers has increased the growth characteristics and yield of the plant (Yousefzadeh et al. 2013).

N2a2h2 treatment had the most significant effect on the percentage of nitrogen in the economic organs of the plant (Table 9). Nitrogen is an essential nutrient for the plants growth and accurate studies have been carried out on this topic. Application of nitrogen fertilizer in the Lamiaceae family has additive effect on the herbage yield of these plants (Barimani 1997). Apparently, the increased use of nitrogen fertilizer has led to increased accumulation of this element in the aerial parts of the plant and also has increased the percentage of nitrogen in leaves and flowers of the plant.

Conclusions

The study results suggested that the use of nitrogenous fertilizers led to increased morphological traits such as the number of lateral branches, number and weight of flowers and the vegetative and economic yield. Probably it is due to the influence of nutrient elements, especially nitrogen on vegetative growth stimulation which has led to the production of more branches in the plant and thus production of more leaves, flowers and economic yield. The other reason of the effect of fertilizers on increased number of branches can be justified in such a way that using nitrogenous fertilizers, the plants have better access to nutrients and it is easier for them to establish. Comparing the application of Azocompost and urea fertilizers for providing the same amount of nitrogen required for wild marjoram, it seems that Azocompost application will cause higher yield compared with urea fertilizer. Economically, given that the value of each kilogram of urea and Azocompost are approximately the same, although Azocompost consumption is much higher than urea fertilizer per hectare, but considering the more yield of plants treated with Azocompost compared to urea fertilizer, Azocompost consumption will be justified. However the environmental justification of using organic fertilizers will also enhance the value of its usage.

References

- Alam, Q.Kh. (2004). Soil Fertility and its management on organic Rice cultivation in Bangladesh. 6th IFOAM- Asia Scientific Conference "Benign Environment and Safe Food" 7th–11th September. Yangpyung / Korea.
- Alizadeh-Sahzabi, A., Sharifi-Ashorabadi, E., Shirani-Rad, A and Abaszadeh, B (2007). The effects of different methods and levels of using nitrogen on some quality and quantity characteristics of *Satureja hortensis* L. Iran J Med Arom Plan 23(3): 416-431.
- Ameri, A.A., Nassiri, M and Rezvani, P. (2007). Effects of different nitrogen levels and plant density on flower, essential oils and extract production and nitrogen use efficiency of Marigold (*Calendula officinalis*). Iran J Field Crops Res 5(2): 315-325.

- Ashraf, B., Yazdani-Biouki, R., Mousavi-Baygi, M and Bannayan-Aval. M. (2014). Investigation of temporal and spatial climate variability and aridity of Iran. Theor Appl Climatol (In press).
- Azizi, A., Yan, F and Honermeier, B. (2009). Herbage yield, essential oil content and composition of three oregano (*Origanum vulgare* L.) populations as affected by soil moisture regimes and nitrogen supply. Ind Crops Prod 29: 554-561.
- Banchio, E., Bogino, P.C., Zygadlo, J and Giordano, W. (2008). Plant growth promoting rhizobacteria improve growth and essential oil yield in *Origanum majorana* L. Biochemical Systematics and Ecology. Biochem Syst Ecol 36(10): 766-771.
- Bannayan-Aval, M., Kaninejad, S., Ghorbani, S and Hesam-Arefi, A. (2011). Evaluation of Plant-to-plant Variability of Medicinal Plants. Iran J Field Crops Res 9(3): 368-378.
- Barimani, M. (1997). Investigating the effects of nitrogen fertilizers at different stages of plant life Deracocephalum moldavica L. and its production of essential oil. M.Sc. Thesis. University of Tarbiat Moallem, Tehran. Iran.
- Dadkhah, A., Amini-Dahaghi, M and Kafi, M. (2012). Effects of Different Levels of Nitrogen and Phosphorous Fertilizers on Yield Quantity and Quality of *Matricaria recutita* L. Iran J Field Crops Res. 10(2): 321-326.
- Dadvand-Sarab, M.R., Naghdi-Badi, H., Nasri, M., Makkizadeh, M and Omidi, H. (2008). Changes in Essential Oil Content and Yield of Basil in Response to Different Levels of Nitrogen and Plant Density. J Med Plant. 7(27): 60-70
- European Pharmacopoeia (Vol. 1) (1983). Maissoneuve, SA: Sainte Ruffine.
- Farahdahr, F., Valad-Abadi, S.A., Daneshiyan, J., Razavipoor, T and Amiri, A. (2011). Effect of irrigation intervals and Azocompost on Agronomic traits in rice (*Oryza sativa*). J Biol Sci. 4(1): 99-111.
- Fariborzi, A. (1999). The effect of nitrogen and on yield and essential oil content in (*Matricaria chamomilla* L.). M.Sc. Thesis. Ferdowsi University of Mashhad. Iran.
- Franz, Ch. (1983). Nutrient and water management for medicinal and aromatic plants. Acta Hortic 132: 203-216.
- Gharib, F.A., Moussa, L.A and Massoud, O.N. (2008). Effect of Compost and Bio-fertilizers on Growth, Yield and Essential Oil of Sweet Marjoram (*Majorana hortensis*) Plant. Int J Agri Biol. 10(4): 381-387.
- Hassani, A. (2006). Effect of Water Deficit Stress on Growth, Yield and Essential Oil Content of *Dracocephalum moldavica* L. Iran J Med Arom Plan 22(3): 261-265.
- Hendawy, S.F. (2008). Comparative Study of Organic and Mineral Fertilization on *Plantago arenaria* plant. J Appl Sci Res 4(5): 500-506.
- Khandan, A. (2005). Effect of organic and chemical fertilizers on soil chemical and physical characteristics and Isabgol. M.Sc. Thesis. Ferdowsi University of Mashhad. Iran.
- Koocheki, A., Tabrizi, L and Ghorbani, R. (2008). Effect of biofertilizers on agronomic and quality criteria of Hyssop *(Hyssopus officinalis).* Iran J Field Crops Res 6(1): 127-137.
- Mahfouz, S.A and Sharaf-Eldin, M.A. (2007). Effect of mineral vs. Biofertilizer on growth, yield and essential oil content of fennel (*Foeniculum vulgare* Mill.). Int Agrophys 21: 361-366.
- Mirjalili, M.H (2001). The economical position of essential oil bearing plants. Zeitun. 156: 26-29.
- Mostaphi-Rad. M., Tahmasebi-Sarvestani, Z., Modarres-Sanavy, S.A.M and Ghalavand, A. (2010). Effect of Nitrogen Sources on Seed Yield, Fatty Acids Composition and Micro

Nutrients Content in High Yielding Rapeseed (*Brassica napus* L.) Varieties. Seed Plan Prod J 2(4): 387-401.

- Omidbaigi, R. (1997). Approaches Processing Medicinal Plants. Vol.2, Trahan Nashr publisher, p. 196.
- Rajeswara, B.R. (2001). Biomass and essential oil yield of rainfed palmorosa (*Cymbopogon citrates*) (Roxb.) Wats. Var. motia Burk.) Supplied with different level of organic manure and fertizer in semi-arid tropical climate. Ind Crops Prod 14: 171-178.
- Salami, M.R., Safarnejad, A and Hamidi, H. (2006). Effect of salinity stress on morphological characters of *Cuminum cyminum* and *Valeriana officinalis*. Pajouhesh & Sazandegi. 72: 77-83.
- Sotiropoulou, D.E and Karamanos, A.J. (2010). Field studies of nitrogen application on growth and yield of Greek oregano (*Origanum vulgare* ssp. hirtum (Link) Ietswaart). Ind Crops Prod 32(3): 450-457.
- Tahmasebi-Sarvestani, Z and Mostafavi-Rad, M. (2011). Effect of Organic and Inorganic Nitrogen Sources on Quantitative and Qualitative Characteristics in Three Winter Rapeseed Cultivars in Arak. Elec J Crop Prod 4(3): 177-194.
- Van-Wyk, B.E and Wink, M. (2004). Medicinal Plants of the World: An Illustrated Scientific Guide to Important Medicinal Plants and Their Uses. P. 386.
- Yousefzadeh, S., Modarres-Sanavy, S.A.M., Sefidkon, F., Asgarzadeh, A., Ghalavand, A and Sadat-Asilan, K. (2013). Effects of Azocompost and urea on the herbage yield and contents and compositions of essential oils from two genotypes of dragonhead (*Dracocephalum moldavica* L.) in two regions of Iran. Food Chem 138: 1407-1413.

Table 1. Latitude, longitude, elevation and annual average of weather variables for the study locations in Iran.

Location	Latitude (N)	Longitude (E)	Elevation (Meter)	Average minimum temperature (◦C)	Average maximum temperature (◦C)	Total precipitation (mm)
Mashhad	36˚ 16′	59˚ 36′	985	7.03	21.18	253.95
Yazd	31˚ 50′	53˚ 59′	1830	11.79	26.58	55.15

Table 2. Soil physico chemical characteristics of experimental locations

Soil properties	EC (ds m^{-1})	pH	Organic carbon (%)	N Availble (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
Yaazd location	2.7	7.3	0.22	9.8	8.48	201
Mashhad location	1.4	7.4	0.19	15	12.8	125

Table 3. Chemical characteristics of azocompost fertilizer used in the experiment

C:N	EC (ds.m^{-1})	pH	Organic carbon (%)	Total N (%)	P (%)	K (%)
10.32	2.9	6.2	28.91	3	1.4	1.34

Table 4. Analysis of variance (mean square) from combined analysis height, canopy area, number of branch, number of flower, total dry weight and dry weight of flower of wild marjoram in response to urea and azocompost in Yazd and Mashhad during 2012-2013 growing season.

S.O.V	**df**	**Height**	**Canopy area**	**Number of branch**	**Number of flower**	**Total dry weight**	**Dry weight of flower**
Location	1	39.42*	20.82^{ns}	99713.74**	27205.25*	1424288.8*	4089.20^{ns}
Block (location)	4	2.09	7.26	1025.89	1434.44	125956.9	50715.30
Urea	3	180.39**	112.58**	35401.53**	68149.49**	2654292.50**	574985.30**
Azocompost	3	186.85**	46.95**	25338.15**	96515.85**	3188603.90**	787309.50**
Ure*Azocompost	9	84.58**	64.31**	10902.40**	33620.71**	1001240.00**	318849.10**
Error a	60	5.37	7.63	801.97	2208.22	65389.50	14970.50
Harvesting time	1	8.75**	16951.39**	6517441.61**	16511056.60**	588061542.20**	113847079.70**
Harvesting time*Urea	3	0.85^{ns}	5.49*	7214.23**	10245.12**	709961.70**	110944.20**
Harvesting time*Azocompost	3	0.56^{ns}	1.38^{ns}	5182.71**	21216.33**	950724.30**	277444.00**
Harvesting time*Urea*Azocompost	9	0.63^{ns}	1.87^{ns}	1824.32**	6893.06**	226567.60**	117290.40**
Location*Urea	3	4.76**	21.26**	845.96^{ns}	1097.00^{ns}	106281.00**	519.80^{ns}
Location*Azocompost	3	1.58^{ns}	11.75**	988.24*	800.86^{ns}	4678.80^{ns}	5620.50^{ns}
Location*Urea*Azocompost	9	5.25**	16.27**	1055.26**	1577.42*	72720.40**	7587.70^{ns}
Location*Urea*Harvesting time	3	0.10^{ns}	10.95**	159.82^{ns}	438.72^{ns}	71793.70*	1550.60^{ns}
Location*Azocompost*harvesting time	3	0.28^{ns}	0.57^{ns}	123.88^{ns}	882.39^{ns}	3046.60^{ns}	10051.10^{ns}
Location*Urea*Azocompost*harvesting time	9	0.67^{ns}	0.22^{ns}	162.07^{ns}	270.08^{ns}	33833.40^{ns}	6922.90^{ns}
Error b	64	0.68	1.52	326.90	772.14	20944.80	7124.60
CV		3.10	3.82	4.63	4.53	4.04	5.31

*, ** and ns significant at the level 0.05, 0.01 and not significant, respectively.

Table 5. Analysis of variance (mean square) from combined analysis dry weight of leaf, economic yield, harvest index, content essential oil, essential oil yield and nitrogen percentage of wild marjoram in response to urea and azocompost in Yazd and Mashhad during 2012-2013 growing season.

S.O.V	df	Dry weight of leaf	Economic yield	Harvest index	Essential oil (%)	Essential oil yield	Nitrogen (%)
Location	1	286002.10*	358531.08ns	141.27**	0.24*	962.67*	0.00006ns
Block (location)	4	15851.10	119242.50	3.85	0.03	94.32	0.003
Urea	3	647506.80**	2438315.20**	112.50**	0.01ns	887.40**	0.21**
Azocompost	3	531868.20**	2609077.30**	38.01ns	0.06**	933.70**	0.009*
Ure*Azocompost	9	272229.40**	1146413.60**	57.08**	0.01ns	381.53**	0.02**
Error a	60	12807.30	45419.40	14.79	0.01	23.84	0.002
Harvesting time	1	109042589.10**	445726026.50**	31.22**	0.09**	127637.11**	0.00008ns
Harvesting time*Urea	3	146870.50**	512189.50**	13.81*	0.002ns	208.41**	0.008*
Harvesting time*Azocompost	3	135119.10**	798101.70**	0.29ns	0.01*	224.85**	0.01**
Harvesting time*Urea*Azocompost	9	65298.30**	333705.20**	15.08**	0.001ns	108.66**	0.006*
Location*Urea	3	1022.30ns	2075.30ns	30.10**	0.01*	18.98ns	0.008*
Location*Azocompost	3	2819.30ns	994.30ns	1.75ns	0.04**	40.90**	0.01**
Location*Urea*Azocompost	9	2665.50ns	5895.40ns	40.75**	0.01**	11.02ns	0.006*
Location*Urea*Harvesting time	3	1207.80ns	3629.40ns	13.88*	0.001ns	7.70ns	0.0009ns
Location*Azocompost*harvesting time	3	1621.80ns	3948.60ns	1.90ns	0.01**	5.25ns	0.006*
Location*Urea*Azocompost*harvesting time	9	1730.60ns	4974.00ns	6.48ns	0.002ns	2.20ns	0.003ns
Error b	64	3295.70	13506.30	3.48	0.002	9.26	0.002
CV		3.69	3.70	2.12	3.26	5.85	4.46

*, ** and ns significant at the level 0.05, 0.01 and not significant, respectively.

Table 6. Mean Comparison of interactions of different urea and azocompost levels on height, canopy area, number of branch, number of flower, total dry weight and dry weight of flower of wild marjoram from mean of Yazd and Mashhad during 2012-2013 growing season.

Treatment	Height (cm)	Canopy area (cm)	Number of branch	Number of flower	Total dry weight (kg ha^{-1})	Dry weight of flower (kg ha^{-1})
n0a0*	18. 16[i] **	24.52[f]	304.47[j]	449.61[g]	2650.80[i]	1197.40[i]
n0a1	24. 50[gh]	29.86[e]	349.91[i]	572.49[ef]	3333.50[h]	1408.70[gh]
n0a2	28. 58[cd]	33.11[abcd]	404.66[de]	640.83[bcd]	3571.80[efg]	1619.90[de]
n0a3	28. 66[cd]	33.00[abcd]	413.51[cd]	665.51[bc]	3960.70[bc]	1744.70[b]
n1a0	25.08[efgh]	32.24[ab]	370.06[ghi]	551.26[f]	3357.90[h]	1358.10[h]
n1a1	29.25[bc]	34.35[ab]	430.79[bc]	676.52[b]	3917.40[cd]	1720.20[bc]
n1a2	32.25[a]	34.54[a]	465.83[a]	721.06[a]	4261.10[a]	1984.50[a]
n1a3	30.66[ab]	31.10[de]	451.42[ab]	715.88[a]	4144.70[ab]	1898.80[a]
n2a0	24.91[fgh]	33.59[abc]	374.06[fgh]	579.18[ef]	3366.40[gh]	1513.80[f]
n2a1	26.83[de]	32.63[abcd]	384.81[efg]	604.12[de]	3693.30[e]	1622.80[cde]
n2a2	26.08[efg]	32.08[cde]	382.92[efg]	605.26[de]	3424.70[fgh]	1474.90[fg]
n2a3	24.41[gh]	32.07[cde]	370.78[ghi]	576.74[ef]	3526.30[efgh]	1501.30[fg]
n3a0	26.66[ef]	33.85[abc]	385.98[efg]	607.23[de]	3430.80[fgh]	1556.80[ef]
n3a1	26.91[de]	34.13[abc]	396.92[def]	635.78[cd]	3586.70[ef]	1630.20[cde]
n3a2	26.58[ef]	33.79[abc]	399.67[de]	619.09[d]	3732.20[de]	1683.60[bcd]
n3a3	24.16[h]	32.57[ab]	354.93[hi]	578.01[ef]	3323.50[h]	1508.20[fg]

* For Yazd and Mashhad n0, n1, n2 and n3 are 0, 43.5, 130.4 and 217.4 and 0, 21.7, 108.7 and 195.7 kg Urea ha^{-1}, respectively. a0, a1, a2 and a3 are 0, 4.4, 13.3 and 22.0 ton Azocompost ha^{-1} for Yazd and 0, 2.2, 11.1 and 20 ton Azocompost ha^{-1} for Mashhad.

** In each column mean a minimum of a joint letter, the 5 percent level, differences are not significant.

Table 7. Mean Comparison of interactions of different urea and azocompost levels on dry weight of leaf, economic yield, harvest index, content essential oil, essential oil yield and nitrogen percentage of wild marjoram from mean of Yazd and Mashhad during 2012-2013 growing season.

Treatment	Dry weight of leaf (kg ha^{-1})	Economic yield (kg ha^{-1})	Harvest index	Essential oil (%)	Essential oil yield (kg ha^{-1})	Nitrogen (%)
n0a0*	1145.50^{f}	2342.80^{g}	88.07^{bcdef}	1.58	37.75^{i}	1.01^{i}
n0a1	1406.80^{e}	2815.50^{f}	85.24^{fg}	1.55	44.19^{h}	1.02^{i}
n0a2	1580.60^{d}	3200.50^{d}	89.89^{abc}	1.72	55.26^{bc}	1.01^{i}
n0a3	1712.80^{b}	3457.40^{c}	87.57^{cdef}	1.63	56.82^{b}	1.04^{hi}
n1a0	1447.50^{e}	2805.60^{f}	85.50^{efg}	1.62	46.04^{gh}	1.08^{fg}
n1a1	1689.50^{bc}	3409.70^{c}	87.35^{cdef}	1.62	55.93^{bc}	1.10^{efg}
n1a2	1962.50^{a}	3947.00^{a}	92.81^{a}	1.68	66.93^{a}	1.07^{gh}
n1a3	1757.20^{b}	3656.10^{b}	88.41^{bcde}	1.72	63.27^{a}	1.12^{cdef}
n2a0	1441.70^{e}	2955.50^{f}	88.02^{bcdef}	1.63	48.58^{efg}	1.10^{cdefg}
n2a1	1563.20^{d}	3186.00^{d}	86.34^{defg}	1.61	51.99^{cdef}	1.14^{cd}
n2a2	1429.50^{e}	2904.40^{f}	85.55^{efg}	1.66	48.34^{fg}	1.24^{a}
n2a3	1465.00^{e}	2966.30^{ef}	83.99^{g}	1.63	48.72^{efg}	1.13^{cde}
n3a0	1576.50^{d}	3133.30^{de}	90.82^{ab}	1.65	52.45^{cde}	1.19^{b}
n3a1	1574.20^{d}	3204.33^{d}	89.23^{bcd}	1.60	52.32^{cdef}	1.10^{defg}
n3a2	1604.70^{cd}	3288.30^{cd}	88.20^{bcdef}	1.62	53.73^{bcd}	1.15^{c}
n3a3	1469.50^{e}	2977.70^{ef}	90.18^{abc}	1.67	50.12^{def}	1.20^{b}

[*] For Yazd and Mashhad n0, n1, n2 and n3 are 0, 43.5, 130.4 and 217.4 and 0, 21.7, 108.7 and 195.7 kg Urea ha^{-1}, respectively. a0, a1, a2 and a3 are 0, 4.4, 13.3 and 22.0 ton Azocompost ha^{-1} for Yazd and 0, 2.2, 11.1 and 20 ton Azocompost ha^{-1} for Mashhad.

[**] In each column mean a minimum of a joint letter, the 5 percent level, differences are not significant.

Table 8. Mean Comparison of interactions of different urea levels and harvesting time on yield, yield components and some traits of wild marjoram from mean of Yazd and Mashhad during 2012-2013 growing season.

Treat ment	**Height (cm)**	**Canopy area (cm)**	**Number of branch**	**Number of flower**	**Total dry weight (kg ha^{-1})**	**Dry weight of flower (kg ha^{-1})**
n0h1*	24.70	21.20^{d} **	193.90^{d}	300.43^{d}	1723.80^{d}	765.51^{e}
n0h2	25.25	39.04^{b}	542.37^{b}	863.79^{b}	5034.60^{b}	2219.83^{c}
n1h1	29.12	23.58^{c}	227.43^{c}	351.72^{c}	1992.00^{c}	903.51^{d}
n1h2	29.50	42.53^{a}	631.62^{a}	980.64^{a}	5848.60^{a}	2577.32^{a}
n2h1	25.20	22.87^{cd}	198.60^{d}	305.13^{d}	1785.60^{cd}	783.11^{de}
n2h2	25.91	42.31^{a}	557.69^{b}	877.52^{b}	5219.70^{b}	2273.25^{bc}
n3h1	26.04	24.12^{c}	203.29^{d}	319.37^{cd}	1818.70^{cd}	823.69^{de}
n3h2	26.12	43.05^{a}	565.46^{b}	900.68^{b}	5217.90^{b}	2365.69^{b}
	Dry weight of leaf (kg ha^{-1})	**Economic yield (kg ha^{-1})**	**Harvest index**	**Essential oil (%)**	**Essential oil yield (kg ha^{-1})**	**Nitrogen (%)**
n0h1	752.38^{e}	1517.90^{e}	88.05^{abc}	1.60	24.44^{e}	1.01^{d}
n0h2	2170.46^{c}	4390.30^{c}	87.33^{bcd}	1.64	72.56^{c}	1.03^{d}
n1h1	883.42^{d}	1786.90^{d}	89.62^{a}	1.64	29.41^{d}	1.09^{c}
n1h2	2544.91^{a}	5122.20^{a}	87.41^{bcd}	1.68	86.66^{a}	1.10^{c}
n2h1	756.42^{e}	1539.50^{e}	86.33^{cd}	1.62	25.01^{e}	1.15^{ab}
n2h2	2193.31^{c}	4466.60^{bc}	85.62^{d}	1.65	73.80^{c}	1.16^{ab}
n3h1	800.00^{de}	1623.70^{de}	89.62^{a}	1.60	26.10^{de}	1.18^{a}
n3h2	2312.43^{b}	4678.10^{b}	89.81^{a}	1.67	78.20^{b}	1.14^{b}

* For Yazd and Mashhad n0, n1, n2 and n3 are 0, 43.5, 130.4 and 217.4 and 0, 21.7, 108.7 and 195.7 kg Urea ha^{-1}, respectively.

** In each column mean a minimum of a joint letter, the 5 percent level, differences are not significant.

Table 9. Mean Comparison of interactions of different azocompost levels and harvesting time on yield, yield components and some traits of wild marjoram from mean of Yazd and Mashhad during 2012-2013 growing season.

Treatment	Height (cm)	Canopy area (cm)	Number of branch	Number of flower	Total dry weight (kg ha^{-1})	Dry weight of flower (kg ha^{-1})
a0h1*	23.54	21.87	188. 81^{e}**	284.80^{d}	1656.40^{d}	743.95^{d}
a0h2	23.87	40.23	528.47^{c}	808.84^{b}	4746.60^{b}	2069.07^{c}
a1h1	26.58	23.33	205.85^{de}	322.68^{cd}	1861.70^{cd}	824.69^{d}
a1h2	27.16	42.15	575.37^{b}	921.77^{a}	5403.80^{a}	2366.24^{b}
a2h1	28.29	23.79	218.96^{d}	304.42^{c}	1901.60^{c}	860.51^{d}
a2h2	28.45	42.97	607.58^{a}	952.70^{a}	5593.30^{a}	2520.93^{a}
a3h1	26.66	22.79	209.60^{de}	328.74^{c}	1900.40^{c}	846.66^{d}
a3h2	27.29	41.59	585.73^{ab}	939.32^{a}	5577.20^{a}	2479.85^{ab}
	Dry weight of leaf (kg ha^{-1})	**Economic yield (kg ha^{-1})**	**Harvest index**	**Essential oil (%)**	**Essential oil yield (kg ha^{-1})**	**Nitrogen (%)**
a0h1	1.10^{ab}	23.39^{e}	1.59^{bc}	88.56	1467.30^{e}	723.33^{e}
a0h2	1.09^{ab}	69.01^{c}	1.65^{a}	87.65	4151.30^{c}	2082.24^{c}
a1h1	1.11^{ab}	25.52^{de}	1.56^{c}	87.51	1629.00^{de}	804.33^{de}
a1h2	1.07^{b}	76.69^{b}	1.63^{ab}	86.57	4678.80^{b}	2312.51^{b}
a2h1	1.09^{ab}	28.42^{d}	1.66^{a}	89.51	1703.60^{d}	843.13^{d}
a2h2	1.14^{a}	83.70^{a}	1.68^{a}	88.72	4966.50^{a}	2445.53^{a}
a3h1	1.12^{ab}	23.63^{de}	1.65^{a}	87.83	1668.10^{de}	821.42^{de}
a3h2	1.12^{ab}	81.83^{a}	1.68^{a}	87.24	4860.60^{ab}	2380.82^{ab}

* For Yazd and Mashhad a0, a1, a2 and a3 are 0, 4.4, 13.3 and 22.0 and 0, 2.2, 11.1 and 20 ton Azocompost ha^{-1}, respectively.

** In each column mean a minimum of a joint letter, the 5 percent level, differences are not significant.

Table 10. Mean Comparison of interactions of different urea and azocompost levels and harvesting time on height, canopy area, number of branch, number of flower, total dry weight and dry weight of flower of wild marjoram from mean of Yazd and Mashhad during 2012-2013 growing season.

Treatment	Height (cm)	Canopy area (cm)	Number of branch	Number of flower	Total dry weight (kg ha^{-1})	Dry weight of flower (kg ha^{-1})
n0a0h1*	17.83	16.50	154.61^{n}**	224.91^{n}	1350.50^{l}	597.92^{m}
n0a0h2	18.50	32.55	454.33^{h}	674.32^{i}	3951.70^{g}	1796.84^{h}
n0a1h1	24.33	21.00	186.11^{m}	296.69^{m}	1707.50^{k}	752.13^{l}
n0a1h2	24.66	38.73	513.70^{g}	848.28^{gh}	4959.50^{f}	2065.33^{f}
n0a2h1	28.16	23.83	212.36^{jklm}	331.08^{klm}	1821.50^{jk}	824.^{jkl}00
n0a2h2	29.00	42.40	596.96^{c}	950.58^{cd}	5322.20^{cd}	2415.81^{cd}
n0a3h1	28.50	23.50	222.51^{jkl}	349.04^{jkl}	2016.40^{hij}	887.98^{jk}
n0a3h2	28.83	42.50	604.50^{c}	981.99^{bc}	5905.00^{b}	2601.35^{b}
n1a0h1	24.83	23.00	196.06^{lm}	293.85^{m}	1737.80^{k}	782.92^{kl}
n1a0h2	25.33	41.49	544.07^{ef}	808.67^{h}	4978.10^{f}	1933.33^{g}
n1a1h1	28.83	24.66	224.18^{jk}	350.95^{jkl}	2002.10^{hij}	884.01^{jk}
n1a1h2	29.66	44.04	637.49^{b}	1002.09^{b}	5832.80^{b}	2556.39^{b}
n1a2h1	32.50	24.66	251.39^{i}	391.78^{j}	2161.70^{h}	1007.75^{i}
n1a2h2	32.00	44.41	680.27^{a}	1050.33^{a}	6360.40^{a}	2961.22^{a}
n1a3h1	30.33	22.00	238.18^{ij}	370.28^{jk}	2066.30^{hi}	939.34^{ij}
n1a3h2	31.00	40.21	664.67^{a}	1061.47^{a}	6223.00^{a}	2858.33^{a}
n2a0h1	24.50	23.66	196.79^{lm}	298.85^{m}	1723.30^{k}	779.02^{kl}
n2a0h2	25.33	43.52	551.33^{e}	859.50^{fg}	5009.50^{ef}	2248.52^{e}
n2a1h1	26.50	23.00	204.49^{klm}	314.92^{lm}	1889.90^{ijk}	827.35^{jkl}
n2a1h2	27.16	33.00	565.53^{de}	893.33^{ef}	5496.60^{c}	2418.21^{c}
n2a2h1	25.83	22.33	201.44^{klm}	313.27^{lm}	1710.40^{k}	757.43^{l}
n2a2h2	26.33	41.83	564.39^{de}	897.25^{ef}	5139.10^{def}	2192.30^{e}
n2a3h1	24.00	22.50	192.07^{m}	293.47^{m}	1818.80^{jk}	768.65^{kl}
n2a3h2	24.83	41.65	459.50^{ef}	860.00^{fg}	5233.70^{de}	2233.96^{e}
n3a0h1	27.00	24.33	207.79^{klm}	321.58^{lm}	1814.50^{jk}	815.94^{kl}
n3a0h2	26.33	43.36	564.17^{de}	892.88^{ef}	5047.20^{ef}	2297.57^{de}
n3a1h1	26.66	24.66	209.09^{klm}	328.17^{klm}	1847.20^{ijk}	835.27^{jkl}
n3a1h2	27.16	43.59	584.76^{cd}	943.39^{cd}	5326.30^{cd}	2425.05^{c}
n3a2h1	26.66	24.33	210.64^{klm}	325.55^{lm}	1912.90^{ijk}	852.88^{jkl}
n3a2h2	26.50	43.26	588.69^{cd}	912.62^{de}	5551.40^{c}	2514.40^{bc}
n3a3h1	23.83	23.16	185.63^{m}	302.19^{m}	1700.00^{k}	790.68^{kl}
n3a3h2	24.50	41.92	524.23^{fg}	853.83^{fg}	4946.90^{f}	2225.74^{e}

* for Yazd and Mashhad n0, n1, n2 and n3 are 0, 43.5, 130.4 and 217.4 and 0, 21.7, 108.7 and 195.7 kg Urea ha^{-1}, respectively. a0, a1, a2 and a3 are 0, 4.4, 13.3 and 22.0 ton Azocompost ha^{-1} for Yazd and 0, 2.2, 11.1 and 20 ton Azocompost ha^{-1} for Mashhad.

** In each column mean a minimum of a joint letter, the 5 percent level, differences are not significant.

Table 11. Mean Comparison of interactions of different urea and azocompost levels and harvesting time on dry weight of leaf, economic yield, harvest index, content essential oil, essential oil yield and nitrogen percentage of wild marjoram from mean of Yazd and Mashhad during 2012-2013 growing season.

Treatment	Dry weight of leaf (kg ha^{-1})	Economic yield (kg ha^{-1})	Harvest index	Essential oil (%)	Essential oil yield (kg ha^{-1})	Nitrogen (%)
n0a0h1*	585.83^{j}	1183.75^{p}	87.60^{efgh}	1.53	18.4^{n}1	1.01^{klm}
n0a0h2	1705.10^{f}	3501.94^{j}	88.55^{defg}	1.63	57.36^{i}	1.01^{klm}
n0a1h1	728.67^{i}	1480.80^{o}	$86.71^{efghijk}$	1.52	22.64^{mn}	1.01^{klm}
n0a1h2	2084.95^{e}	4150.28^{hi}	83.77^{jkl}	1.58	65.73^{h}	1.03^{jklm}
n0a2h1	814.33^{hi}	1638.33^{mno}	90.10^{abcd}	1.72	28.25^{kl}	0.99^{m}
n0a2h2	2346.92^{d}	4762.73^{ef}	89.68^{bcdef}	1.72	82.25^{cd}	1.02^{klm}
n0a3h1	880.67^{h}	1768.65^{lm}	87.80^{defgh}	1.62	28.71^{kl}	1.01^{klm}
n0a3h2	2544.87^{bc}	5146.22^{c}	87.33^{efghi}	1.65	84.91^{c}	1.07^{hijk}
n1a0h1	754.17^{i}	1537.08^{no}	88.94^{cdefg}	1.59	24.44^{lm}	1.08^{ghij}
n1a0h2	2140.73^{e}	4074.07^{i}	82.43^{l}	1.65	67.63^{gh}	1.09^{ghij}
n1a1h1	877.00^{h}	1761.01^{lm}	87.96^{defg}	1.58	27.89^{kl}	1.11^{fghi}
n1a1h2	2501.93^{c}	5058.32^{cd}	$86.74^{efghijk}$	1.65	83.96^{c}	1.09^{ghij}
n1a2h1	1005.83^{g}	2013.59^{k}	93.15^{a}	1.67	33.74^{j}	1.06^{ijkl}
n1a2h2	2919.19^{a}	5880.41^{a}	92.46^{ab}	1.70	100.11^{a}	1.09^{ghij}
n1a3h1	896.67^{h}	1836.00^{kl}	88.80^{cdefg}	1.72	31.59^{jk}	1.11^{fghi}
n1a3h2	2617.77^{b}	5476.10^{b}	88.01^{defg}	1.73	94.95^{b}	1.12^{defg}
n2a0h1	743.33^{i}	1522.35^{no}	88.38^{defg}	1.61	24.66^{lm}	1.12^{defg}
n2a0h2	2140.07^{e}	4388.59^{g}	87.66^{efgh}	1.65	72.50^{f}	1.09^{ghij}
n2a1h1	805.00^{hi}	1632.35^{mno}	86.44^{fghijk}	1.59	26.05^{lm}	1.17^{bcde}
n2a1h2	2321.48^{d}	4739.70^{ef}	86.25^{ghijk}	1.64	77.92^{de}	1.12^{defg}
n2a2h1	727.67^{i}	1484.76^{no}	86.95^{efghij}	1.66	24.71^{lm}	1.17^{bcde}
n2a2h2	2131.68^{e}	4323.97^{gh}	84.14^{ijkl}	1.66	71.95^{fg}	1.31^{a}
n2a3h1	750.00^{i}	1518.65^{no}	83.53^{kl}	1.62	24.61^{lm}	1.16^{bcdef}
n2a3h2	2180.00^{e}	4413.96^{g}	84.44^{hijkl}	1.65	72.82^{f}	1.10^{fghi}
n3a0h1	810.00^{hi}	1625.94^{mno}	89.67^{bcdefg}	1.62	26.32^{lm}	1.21^{b}
n3a0h2	2343.07^{d}	4640.64^{f}	91.98^{abc}	1.69	78.56^{de}	1.18^{bcd}
n3a1h1	806.67^{hi}	1641.94^{lmno}	88.94^{cdefg}	1.55	25.50^{lm}	1.15^{cdef}
n3a1h2	2341.68^{d}	4766.73^{ef}	89.52^{bcdefg}	1.65	79.13^{de}	1.06^{ijkl}
n3a2h1	825.00^{hi}	1677.88^{lmn}	87.83^{defgh}	1.60	26.97^{lm}	1.16^{bcdef}
n3a2h2	2384.32^{d}	4898.72^{de}	88.58^{cdefg}	1.64	80.47^{cd}	1.13^{defg}
n3a3h1	758.33^{i}	1549.02^{no}	91.18^{abcd}	1.65	25.60^{lm}	1.20^{bc}
n3a3h2	2180.65^{e}	4406.31^{g}	89.61^{bcdefg}	1.69	74.63^{ef}	1.19^{bc}

[*] for Yazd and Mashhad n0, n1, n2 and n3 are 0, 43.5, 130.4 and 217.4 and 0, 21.7, 108.7 and 195.7 kg Urea ha^{-1}, respectively. a0, a1, a2 and a3 are 0, 4.4, 13.3 and 22.0 ton Azocompost ha^{-1} for Yazd and 0, 2.2, 11.1 and 20 ton Azocompost ha^{-1} for Mashhad.

[**] In each column mean a minimum of a joint letter, the 5 percent level, differences are not significant.