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Evaluation of Yield, Nitrogen Use Efficiency and Radiation Use Efficiency of Wild Majoram in Response to Organic and Chemical Fertilizers

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Abstract

In order to investigate the effect of urea and Azocompost on economic yield, nitrogen use efficiency (NUE) and radiation use efficiency (RUE) of wild majoram, a factorial 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) were considered as the main factors. Characteristics of the study include the economic yield (leaf and flower dry matter), nitrogen percentage of herbage yeild, NUE and RUE. The combined analysis of two locations results revealed signfficant effects two treatments of urea and azocompost on economic yield ($P<0.05$). The highest yield in urea and azocompost treatments were equal to 1625.94 and 1768.65 kg ha^{-1} that was obtained from 120 kg N ha^{-1} treatment, respectively. Application of organic and chemical fertilizers due to decrease NUE and increase RUE compared to control plants in both of regions. RUE in Mashhad location with 0.9 gr MJ^{-1} was more than Yazd location with 0.75 gr MJ^{-1} in control treatment. Overall, Application of azocompost caused higher yields, NUE and RUE than urea treatment.

Key words: Azocompost, Mashhad, PAR, Urea, Yazd.

Introduction

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). Preserving the environment and achieving sustainable development is one of the main issues with the implementation of comprehensive plans for economic and social goals of the different countries of the world including our country has. One of the strategies to reduce the use of chemical fertilizers and pesticides and increased efficiency, the use of organic materials (Mostaphi Rad et al. 2010). Increasing the efficiency and productivity of resource use, the most important step to achieve sustainability (Caviglia, 2004). Use appropriate amounts and sources of nitrogen, so that the highest efficiency of plants and reduce the environmental pollution is among the crucial part of the management of nitrogenous fertilizers (Lany et al, 1999). Nitrogen plays an important role in creating optimal qualitative and quantative yield of the

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plants; however this element is easily leached from the soil and results in contamination of water and reduction of nitrogen usage efficiency (Foulkes et al, 1998). 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). 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*).

Ameri and Nasiri (2008) with effects of nitrogen application and plant densities on flower yield, essential oils, and radiation use efficiency of Marigold (*Calendula officinalis* L.) revealed significant effects of nitrogen on flower dry matter production and radiation use efficiency of Marigold. 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 the different effects of different nitrogen sources on growth and yield of medicinal plants are grown. Comparison of different levels of urea and azocompost fertilizers on yield, NUE and RUE of wild marjoram is necessary to reach.

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 dry matter and economic yield. 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.

With using daily sunshine extracted from both the Institute of Climatology, Mashhad, Yazd, solar radiation with using method Goudriaan and Van Laar (1993) were calculated. The amount of light absorbed was calculated from equation 1:

Ii = I (1 - exp) : Equation 1

Ii, the amount of radiation absorbed by the canopy, Io, radiation levels have risen above the canopy. To estimate the cumulative amount of radiation absorbed order to assess daily LAI canopy is used in Equation 2 was used (Tsuboi et al, 2001):

$y = a + b / (1 + \exp (- (x-c) / d))$: Equation 2

To calculate the cumulative amount of radiation absorbed in the whole growing season, the integral radiation absorbed per day was used. The light use efficiency by calculating the slope of the regression of dry matter (g m^{-1}) and cumulative radiation (MJ m^{-2}) is calculated (Tsuboi et al, 2001).

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

Results and discussion

Economoc yield

The combined analysis of two locations results revealed signfficant effects two treatments of urea and azocompost on economic yield (P<0.05). The highest yield in urea and azocompost treatments were equal to 1625.94 and 1768.65 kg ha^{-1} that was obtained from 120 kg N ha^{-1} treatment, respectively (Fig 1). 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.

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. 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). 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.

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).

Agronomic N-use efficiency

Results indicate that the application of nitrogen due to reduced agronomic N-use efficiency in both of chemical and organic treatments (Table 4). Application of 40 kg Azocompost ha^{-1} with 22/35 (gr leaves and flowers gr^{-1} N^{-1}) was better than two other levels (Table 4). Application Azocompost in higher level had higher agronomic N-use efficiency than urea treatment. Ameri et al (2007) with application of different levels of nitrogen on Marigold, were reported that agronomic N-use efficiency was reduce with nitrogen consumption. Sharifi and Abbaszadeh (2003) with examining the effects of feeding methods on the quality of the herb fennel (*Foeniculum vulgare*) showed increasing nitrogen fertilizer caused to decreasing NUE.

N-physiological efficiency

Physiological efficiency indicator kg flower and leaf dry matter yield per kg N absorbed. Increased levels of chemical nitrogen on physiological efficiency had no significant effect at 5% level (Table 4). But organic Nitrogen levels significantly increase nitrogen use efficiency (Table 4). So that the levels of 80 and 120 kg N ha^{-1}, with 55.36 and 99.07% due to increased N- physiological efficiency, respectively.
In this experiment, given that the percentage of N increased vegetative body nitrogen did not change much, but the plant is increased, thus increasing Nitrogen physiological efficiency of nitrogen in both chemical and organic treatments was increased. But in other studies by stimulating increased use of nitrogen fertilizer increased nitrate uptake and nitrogen saturation of metabolic processes, which reduces the proportion of C/N is due to the increased use of nitrogen fertilizers and nitrogen physiological efficiency has been noted (Jiang and Hull, 1998).

N-recovery efficiency

According to Table 4, with increasing nitrogen utilization, N-recovery efficiency in both organic and chemical treatments were reduced. So that the treatments of urea and Azocompost by 40 kg N ha^{-1}, N-recovery efficiency was 80.66 and 76.68, respectively. With increasing use of nitrogen from 40 to 80 kg of nitrogen, uptake efficiency, for urea and Azocompost was 60.08 and 58.38, respectively (Table 4). Increasing levels of 40 to 120 kg N ha^{-1}, N-recovery efficiency reduced equal to 67.88 and 66.01 in chemical and organic treatments, respectively (Table 4). Ameri et al (2007) in their studies on medicinal plants Marigold reported that the increasing use of nitrogen fertilizer, recovery efficiency was reduced. So they showed that consumption of 50 kg of nitrogen due to 68.77 percent efficiency and by increaseing N to 100 and 150 kg N ha^{-1}, compared to 50 kg of nitrogen utilization efficiency reduced to 15.98 and 6.11 percent, respectively. Studies Ram et al (2003) with the use of different levels of nitrogen fertilizer on herb Geranium (*Pelargonium graveolens*) showed increased uptake of N up to 160 kg ha^{-1}. They showed that increasing nitrogen fertilizer application increased plant tissue nitrogen and dry matter yield ha^{-1}. And application N more than 160 kg ha^{-1}, N-recovery efficiency was reduced so that much of the nitrogen intake did not affect the growth of crops. 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.

Radiation use efficiency

Increased use of chemical fertilizers and organic nitrogen in comparison with control RUE was increased in both areas (Figures 6, 7, 8 and 9). RUE in three levels of 40, 80 and 120 kg N ha^{-1} had a slight difference. Organic nitrogen level of 120 kg ha^{-1} with 0.01 g MJ^{-1} compared to treated urea in the same level produces more RUE in both of regions Mashhad and Yazd. Management, environmental and plant factors such as nitrogen status of the plant, nitrogen fertilization, temperature, location, culture, environmental stresses such as drought rate changes are effective RUE (Board, 2000). The difference in RUE could be due to the differences in the allocation of materials between roots and shoots, or due to differences in photosynthetic active radiation is absorbed (Siddique et al, 1989). Increasing RUE by nitrogen fertilizer use in several experiments have been reported. Akmal and Janssens (2004) study on permanent Rygras (*Lolium perenne* L.) were reported with sufficient nitrogen application, RUE increased. RUE in both treatments in Yazd was lower than in Mashhad. For example, RUE in control treatment was 0.90 and 0.75 g MJ^{-1} in Mashhad and Yazd regions, respectively (Figure 4 and 5). Kooman and Haverkort (1995) reported that temperatures above 20°C rise in per degree Celsius temperature, RUE by as much as 0.02 g MJ^{-1} diminishes.

Conclusions

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, NUE and RUE 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.

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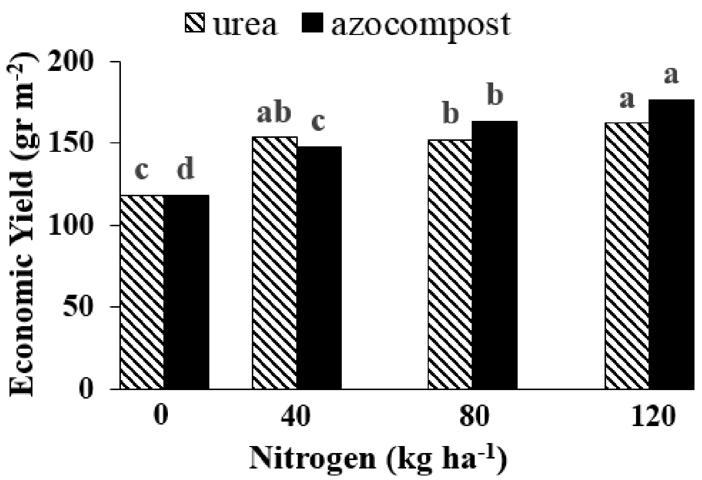


Fig 1. Effect of levels of urea and azocompost on economic yield ((leaf and flower dry matter) Wild majoram from mean of Yazd and Mashhad during 2012-2013 growing season.

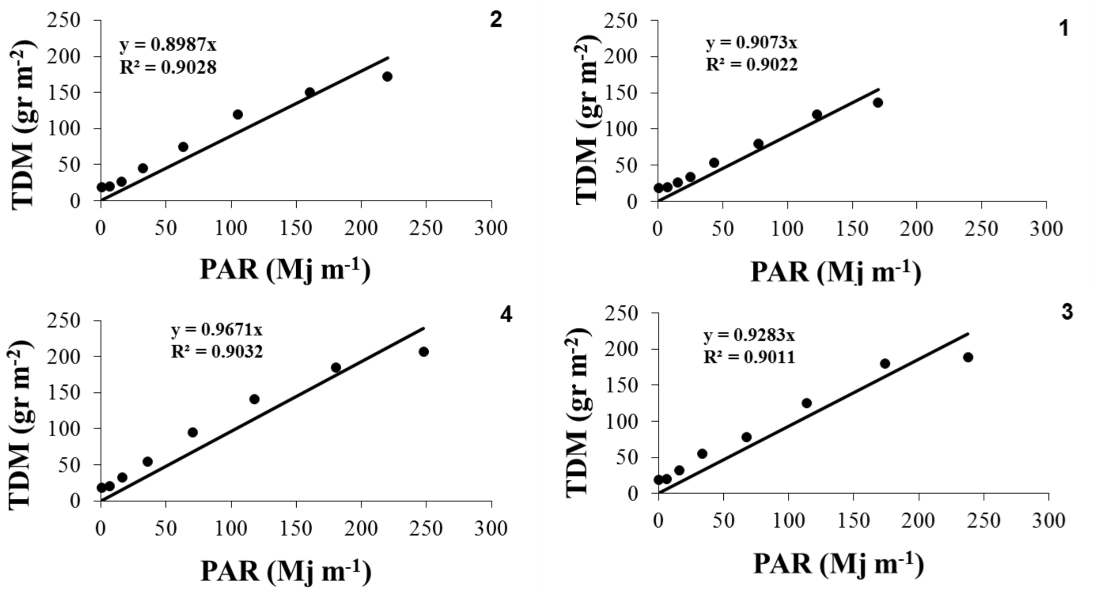
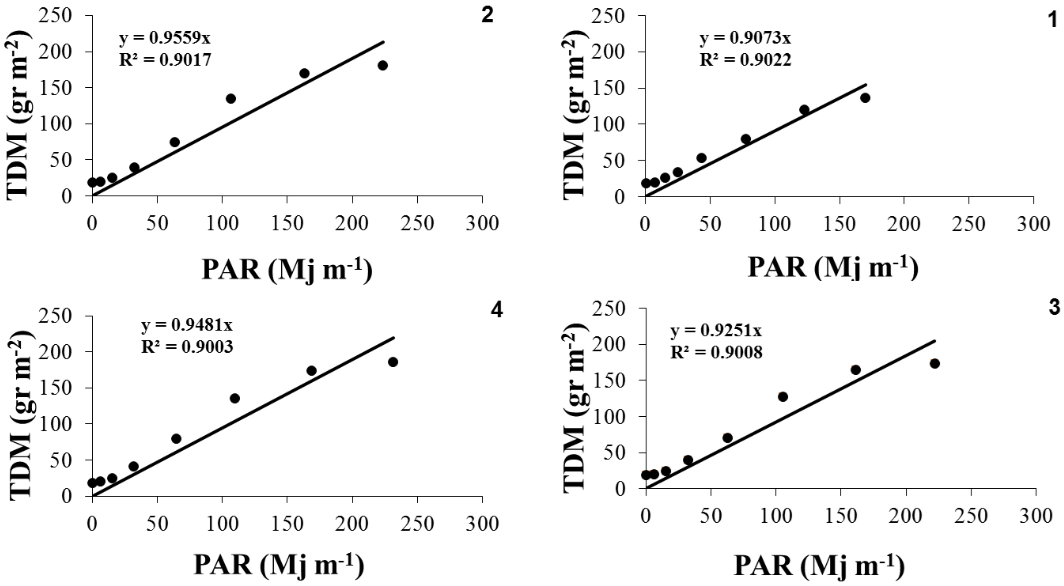


Fig 2. Relationship between total dry weight and photosynthetically active radiation Wild marjoram in Mashhad location, different levels of fertilizer azocompost: 1- control, 2- 40 kg N ha^{-1}, 3- 80 kg N ha^{-1}, and 4- 120 kg N ha^{-1}.



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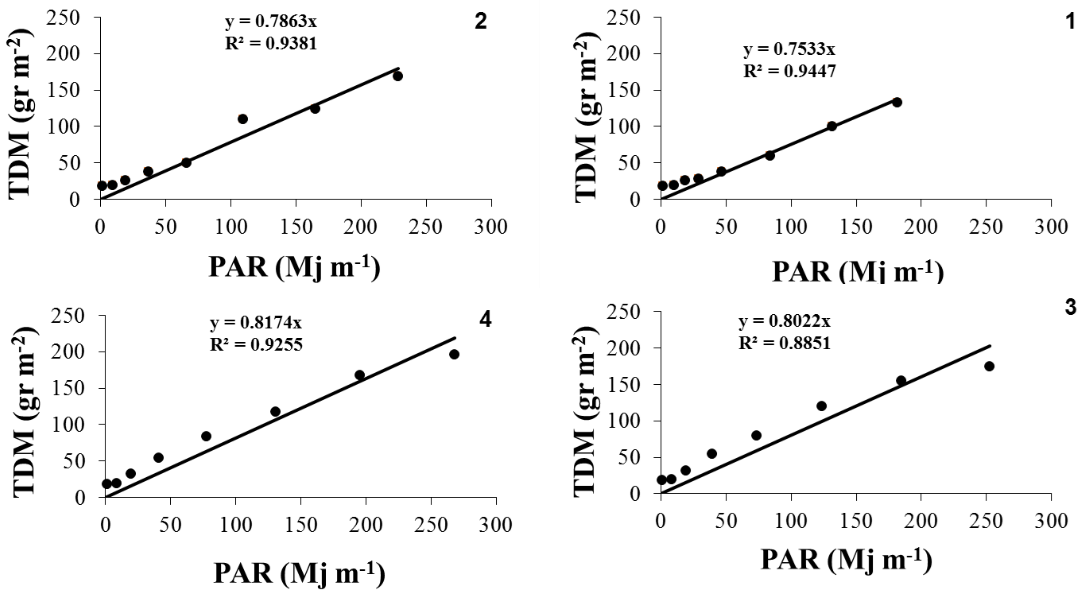

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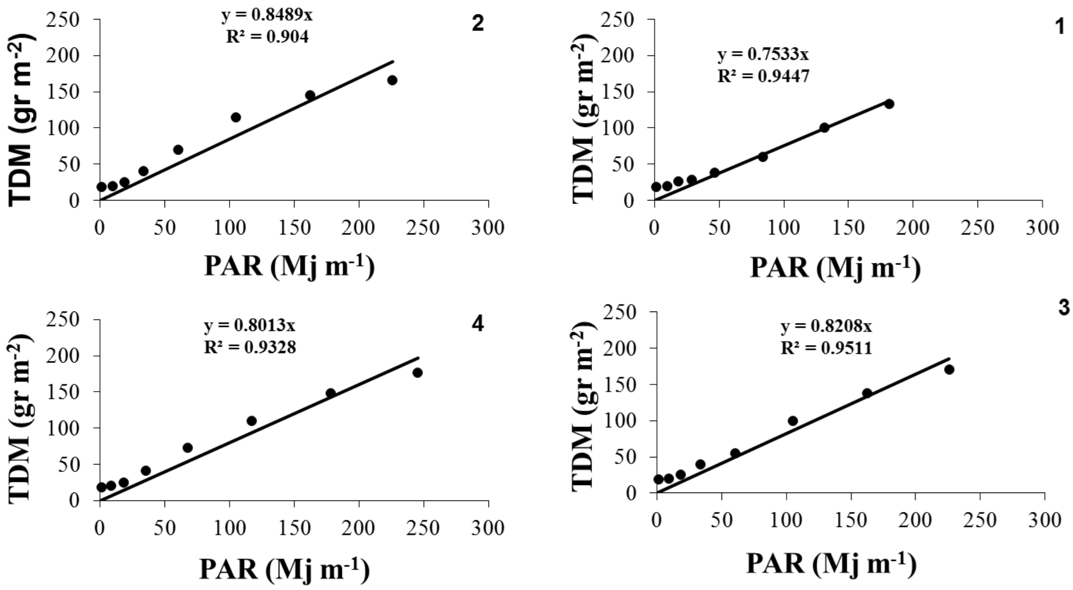

Fig 4. Relationship between total dry weight and photosynthetically active radiation Wild marjoram in Yazd location, different levels of fertilizer urea: 1- control, 2- 40 kg N ha^{-1}, 3- 80 kg N ha^{-1}, and 4- 120 kg N ha^{-1}.

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)
Yazd	31˚ 50′	53˚ 59′	1830	11.79	26.58	55.15
Mashhad	36˚ 16′	59˚ 36′	985	7.03	21.18	253.95

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. Effect of urea and azocompost on nitrogen use efficiency of Wild majoram of Yazd and Mashhad during 2012-2013 growing season

Urea (kg N ha^{-1})	Nitrogen (%)	Agronomic N-use efficiency (kg flower and leaf dry matter yield per kg N applied)	physiological efficiency (kg flower and leaf dry matter yield per kg N absorbed)	N-recovery efficiency (kg N absorbed per kg N applied)
0	*1.01[a]	-	-	-
40	1.08[b]	26.30[a]	32.78[a]	80.66[a]
80	1.12[c]	6.19[b]	30.43[a]	20.58[b]
120	1.21[d]	4.66[b]	36.57[a]	12.78[c]
Azocompost (kg N ha^{-1})				
0	1.01[a]	-	-	-
40	1.01[a]	22.35[a]	29.28[c]	76.68[a]
80	0.99[a]	8.32[b]	45.49[b]	18.30[b]
120	1.01[a]	6.17[b]	58.29[a]	10.67[c]

* Similar letters in each treatment, indicating no significant difference between the levels of urea and Azocompost according to Duncan's test at 5% level.