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Investigating the Growth of *Tagetes* in Different Fertilization with the Production of Complete Fertilizers in Various NPK Ratios

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Abstract

The method of fertilization and fertilizing the soil and culture substrates has an important role in the quantitative and qualitative production of agricultural and horticultural products. Four types of fertilizer formulas with different ratios of N, P and K and constant amounts of micronutrients were prepared as complete liquid fertilizers in the Soil Science Laboratory of Sheikh Baha'i Laboratory Complex, Islamic Azad University, Science and Research Branch, Tehran. In a randomized complete design, the effect of thirteen different fertilizer treatments along with a control including the use of different fertilizers at different times of vegetative and reproductive growth and each treatment in four replications on the growth of *Tagetes* was evaluated. Vegetative growth indices including final plant height, number of flowers and lateral branches, fresh and dry weight of roots, flowers and shoots were evaluated. Overall results showed that different fertilization methods and different fertilizer formulas had a positive effect on plant growth compared to the control. Changes in plant growth were significant compared to the control in fertilization methods and formulas. The best effect on plant growth was seen in treatment number 6 and this treatment is recommended for the growth of this variety of *Tagetes*. In this treatment, in the fourth week of planting seedlings from the first formula including the base ratio of nitrogen, phosphorus and potassium, 15-15-15 and in the fifth and sixth weeks of the second formula including the ratio of base nitrogen, phosphorus and potassium, 15-20 -30, was used.

Keywords: Complete fertilizer, Fertilization, Micronutrient, Plant nutrition, *Tagetes*.

INTRODUCTION

Nutrition plays an essential role in plant growth (Mohammadi Torkashvand *et al*., 2020). The increase in world agricultural production over the past four decades has been largely due to the use of fertilizers after rainfall and irrigation. Optimal fertilizer application is one of the most important factors to increase yield, improve the quality of agricultural products and the health of the community (Zahedyan *et al*., 2020). Optimal fertilizer use is the most effective, easiest and most economical way to achieve the yield of agricultural products (Malakouti *et al*., 2005). One of the major concerns of plant nutritionists in this century is how to increase the efficiency of fertilizer application (FUE). Timely supply of fertilizers based on the plant needs will improve the quantity and quality and prevent environmental pollution (Malakouti *et al*., 2008). The positive effects of nutrient consumption in agriculture have been known for over 2000 years (Barker and Pilbeam, 2007). In general, minerals are essential for plant growth (Ashourzadeh *et al*., 2016).

Nitrogen (N) is one of the most important nutrients and a key factor in achieving optimal yield in crops (Zahedyan *et al*., 2022). In most plants, the use of nitrate nitrogen increases pure photosynthesis and thus increases materiality and yield (Mohammadi *et al*., 2021). For this reason, its high consumption stimulates vegetative growth, increases leaf chlorophyl and delays the formation of flowers and fruits (Malakouti *et al*., 2008). The experiments of Mohammadi *et al.* (2021) showed that there is a direct relationship between the amount of used nitrogen to the plant and the vegetative growth. Organic matter strongly affects the amount of nitrogen in the soil. In soils with high levels of organic matter, the amount of nitrogen fertilizer application is very low (Tashakkori *et al*., 2021).

Potassium, like nitrogen, phosphorus, and sulfur, is not a required component of components such as protoplasm, fats, and cellulose, and its role is primarily catalytic (Barker and Pilbeam, 2007). However, potassium plays a key role in a number of physiological functions, including carbohydrate and protein metabolism, starch formation, degradation, enzyme activation, and regulation of stomatal motility (Mohiti *et al*., 2011). Potassium activates enzymes. There are more than 50 species of enzymes that are either completely dependent on or stimulated by potassium (Barker and Pilbeam, 2007). Phosphorus is one of the most important elements needed in the production of the product. Phosphorus is involved in all biochemical activities, energy compounds and energy transfer mechanisms (Ramezanzadeh *et al*., 2014). This element is involved in flower germination, fruit formation, acceleration of ripening, increasing the vegetative growth of the tree, increasing the size of the tree and increasing the quality of the fruit (Malakouti, 2000).

Effective fertilizer application includes making the right decisions about the choice of nutrients, determining the amount of each nutrient required, the type of fertilizer or fertilizer carrier, how to apply fertilizer and finally the time of fertilizer application (Malakouti *et al*., 2008). Fertilizer application methods depend on several factors such as the degree of solubility of fertilizers, the time required by trees, physical and chemical properties of soils, irrigation water quality, etc. (Majidi *et al*., 2019). Among the application methods can be surface diffusion method, Foliar spraying, injection into tree trunks, fertilizer water and manure (Malakouti *et al*., 2005) were mentioned. The aim of this study is to investigate the use of different fertilizers at different times on the vegetative and reproductive growth of Tagetes.

MATERIALS AND METHODS

The location of experiment and test plant

This research was conducted in the spring and summer of 2020 in the greenhouse of Islamic Azad University, Science and Research Branch, Tehran. In this study, Tiashan cultivar of marigold (*Tagetes erecta*) was used. The benchmark (test plant) in this study was marigold. Marigold flower with the scientific name of *Tagete* spp. belongs to the Asteraceae family and is a spring and summer

annual plant. Marigold is a sun-loving plant and grows well in sunny and warm places (Daneshvar, 1993). It is not sensitive to soil fertility, but good and fertile soils cause the plant to grow well and thus produce large flowers (Dole and Wilkins, 1999). If the amount of nitrogen in the soil increases, the plant becomes susceptible to some diseases. This plant is also relatively sensitive to high humidity (Daneshvar, 1993). This experiment was performed in the form of randomized complete with four replications.

Preparation of fertilizers

Liquid chemical fertilizers raw materials including urea, potassium sulfate, ammonium nitrate, iron, zinc and copper chelates and other materials were prepared. Four different fertilizer formulas with different ratios of nitrogen, potassium and phosphorus and a constant amount of micro elements were prepared in the laboratory.

1- The first formula includes the base ratio of nitrogen, phosphorus and potassium, 15-10-15,
2-The second formula includes the base ratio of nitrogen, phosphorus and potassium, 15-20-30,
3- The third formula includes the base ratio of nitrogen, phosphorus and potassium, 15-20-15,
4- The fourth formula includes the base ratio of nitrogen, phosphorus and potassium, 15-20-45.

The amounts of salts related to microelements were weighed and dissolved in a certain amount of water according to the required amount of each fertilizer formula. This value was the same for all four fertilizer formulas for micronutrients. Then, according to the fertilizer formula, the salts of the high-consumption elements were weighed and dissolved in water. Fourteen treatments were applied in 14 fertilization schedules according to table 1. In table 1, the numbers indicate the number of fertilizer formulas used in that week.

Planting media and its preparation

Cocopeat and peat substrates (50:50 v/v) were used as planting medium. The cocopeat used in this experiment was prepared in molds with dimensions of 12 × 28 × 28 cm weighing 4.5 to 5 kg. Each mold was soaked in water to separate the compressed coconut fibers. The amount of water used to soak each of the coco peat molds was 8 to 10 liters. The compaction of the molds was 5:1, ie the cocopeat molds reached 5 times their volume after dewatering and drying. Dried coconuts were ready to use in pots.

Table 1. Fertilization program of plant in experiment greenhouse in different treatments during the growth time (week).

Treatment number	4th week	5th week	6th week	7th week	8th week
1 (control)	Without application of fertilizer				
2	1*	1	1	-	-
3	2	2	2	-	-
4	3	3	3	-	-
5	4	4	4	-	-
6	1	2	2	-	-
7	1	3	3	-	-
8	2	3	3	-	-
9	4	2	2	-	-
10	4	3	3	-	-
11	1	1	2	2	2
12	1	1	3	3	3
13	4	4	2	2	2
14	4	4	3	3	3

* The number of fertilizer formula.

Post-planting care

Irrigation was done manually with a sprinkler and the irrigation cycle was adjusted according to the needs of the plant. The fertilization program was performed according to table 1 during the growing season of plant. In each treatment, 2.5 ml of fertilizer formula was dissolved per liter of water and sprayed on plants in different repetitions in the morning. Since the experiment was conducted in spring and summer, the cooling system was installed in the greenhouse to control the proper temperature. Roof cooling systems were used to ventilate and cool the greenhouse, and the greenhouse temperature was 15 to 20 degrees Celsius. Marigold is classified as an optional short-day plant. No additional light was needed and natural light was used.

Plant harvesting and measurement of growth indices

After 70 days of planting seedlings, cut the plants from the crown and after washing three times with distilled water, plant height, number of lateral branches, stem diameter, flower size, flower weight, number of buds, flower height, fresh weight of a aerial, shoot dry weight, root fresh weight and root dry weight were measured. Fig. 1 shows the plant harvest.

Fig. 1. Harvesting shoot of marigold.

Plant height from soil surface to terminal flower was measured by a ruler in centimeters. At harvest time, the number of lateral branches was counted and recorded. The diameter of the stems was measured with a digital caliper. Flower diameter was measured at harvest time by digital caliper. After harvest, the flowers were measured in grams using a digital scale. The number of buds was counted and recorded at harvest time. After harvest, aerial parts including stems, leaves and flowers were weighed in grams using a digital scale. After separation from the soil, the roots were weighed in grams using a digital scale (Fig. 2). After placing the plant in the oven for 72 hours at 75 °C, the dry weight of shoots and roots were weighed separately using a digital scale in grams.

Data analysis

Analysis of variance of data was performed using SPSS software. LSD test was used to compare the means and the relevant graphs were drawn using Excel software.

Fig. 2. Measurement of root and shoot weight.

RESULTS AND DISCUSSION

The effect of culture media on plant growth characteristics

The results of analysis of variance (Table 2) showed that the effect of culture media on plant height, number of lateral branches, stem diameter, number of buds, flower weight, flower diameter, shoot fresh weight, shoot dry weight, root fresh weight and root dry weight was significant at the 1% level, only the number of buds was not significant. In this research, foliar application method was used in plant fertilization. In terms of environmental pollution (soil and water), it is much less harmful than soil nutrition of plants, since it is directly related to the plant and less contaminates soil and subsurface water (Tomimori *et al*., 1995). El-Naggar (2009) examined foliar fertilization at different stages of flower growth and concluded that the volume of chlorophylls a and b, carotenoids, carbohydrates and leaf minerals (N, P, K, Zn, Cu) significantly increase in compare to other fertilization methods. Fawzy *et al.* (2007) reported the effects of foliar application and soil nutrition on eggplant as follows: Plant growth characteristics including plant length, number of branches per plant, number of leaves per plant and fresh weight of the plant and plant quality characteristics including diameter, length and mean weight of fruit with simultaneous application of foliar and soil nutrition had a significant increase.

Plant height

Fig. 3 shows the effect of different treatments on plant height. The results showed that the highest plant height was related to plants grown in fertilization treatment No. 6 and then, treatments 5 and 8. The lowest plant height was related to the control treatment (Fig. 3). In treatment 6,

Table 2. Analysis variance of data related to the effect of different treatments on the growth indices of plant.

S.o.V	df	MS							
		Height	Lateral branche No.	Flower No.	Flower stem	Bud No.	Stem diameter	Fresh weight of shoot	Dry weight of shoot
Treatment	13	12.91**	5.71**	0.25**	3.26ns	3.41**	0.02**	12.91**	0.54**
Error	26	1.8	0.75	0.04	3.1	0.5	0.002	2.6	0.08
CV (%)	-	7.4	10.2	12.6	15.4	6.6	8.7	8.2	11.2

** and ns: significant at P<0.01 and insignificant, respectively.

fertilization was done in only three weeks with formula 1 and 2 fertilizers, which included a combination of 15-15-15 and 15-20-30 NPK elements (although in the figures, this treatment is marked with label number 5). Fig. 4 shows the difference in height of the weakest control treatment compared to the superior treatments. Tantawy *et al*. (2010) investigated phosphorus and potassium spraying on squash and showed that the plant growth parameters including height, number of leaves, fresh and dry weight of branches and total fruit weight was observed at highest level of 3 g/l treatment. Other reports have highlighted the positive aspects of foliar application in flowers such as roses (Sharaf and El-Naggar, 2003), Tuberose (Pal and Biswas, 2005) and irises (Mahgoub *et al*., 2006). In an experiment conducted in Alexandria, Egypt in 2006 and 2007, foliar foliar application of 6 different treatments including 4 macro and 6 micro elements on growth and flowering of carnation, Redsim cultivar were investigated. The results showed that flowering parameters such as diameter, fresh and dry weight of flowers increased and the number of days of flowering decreased. Also, length, diameter, fresh and dry weight of stem and number, fresh and dry weight of leaves increased significantly. In addition, in leaf analysis, it was observed that chlorophylls a and b, carotenoids, carbohydrates and minerals in leaves such as N, P, K, Zn and Cu were significantly increased (El-Naggar, 2009).

Improving fertilization conditions and efficiency is key to achieving sustainable production as well as minimizing environmental damage while maintaining the quantity and quality of products (Mohammadi Torkashvand *et al*., 2019). One of the factors that may impair the efficiency of NPK fertilizers is their separate use because if these fertilizers are used together, they can play an effective role in the vital functions of the plant due to their interaction. On the other hand, it should be noted that the effect of ions and nutrients on each other may cause deficiency or excess of some elements in the soil and plants, which excessive use of nitrogen fertilizers has the same effect on the plant (Bergmann, 1992).

Number of lateral branches

The highest number of lateral branches was seen in treatment number 3. In this treatment, only fertilizer formula No. 2 was used in weeks of fourth, fifth and sixth growth (Fig. 5). The lowest number of lateral branches was observed in the control treatment. In treatments 5, 6 and 10, the number of lateral branches was more than other fertilizer and control treatments.

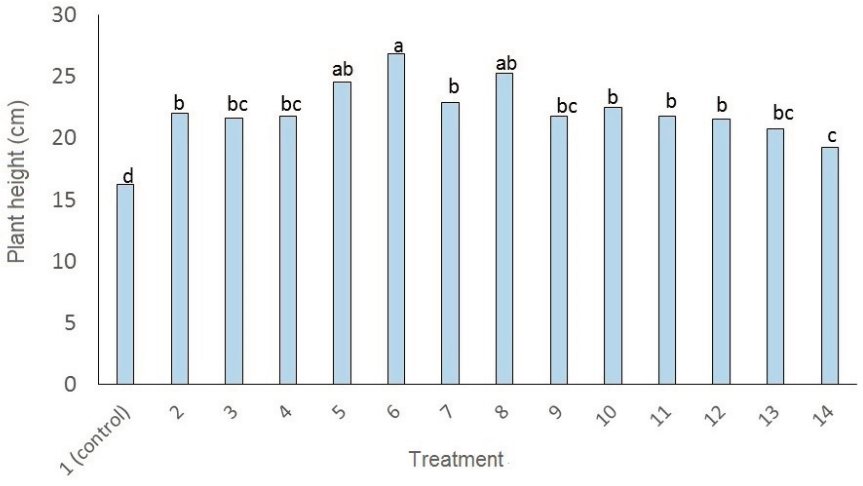

Fig. 3. The effect of different fertization treatments on the height of plant.

Fig. 4. Comparison of plant height in some fertilization treatments
(The treatment number 6 has been labelled by number 5).

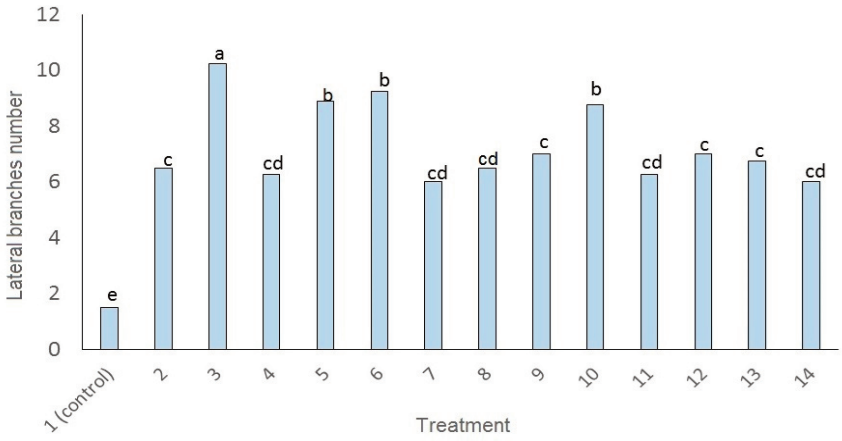

Fig. 5. Effect of different fertilization methods on the number of lateral branches.

Number of buds

Fig. 6 shows the effect of different fertilizer times and formulas on the number of buds. The highest number of buds was seen in treatment number 13. In this treatment, in the fourth and fifth weeks, the fourth formula included the base ratio of nitrogen, phosphorus and potassium, 15-20-45 was used, which included 3 times the concentration of nitrogen compared to formula 1. In the sixth, seventh and eighth weeks, fertilizer formula 3 was used with the basic ratio of nitrogen, phosphorus and potassium, 15-30-30, the amounts of phosphorus and potassium as effective elements in reproductive processes are twice as much as fertilizer formula 1. This has led to a sharp increase in the number of buds. Akanbi *et al*. (2010) investigated the effect of four treatments of NPK fertilizer (0, 200, 300 and 400 kg/ha) and three planting times (5, 6 and 7 weeks) after sowing seeds of eggplant. The best fertilizer treatment was 300 kg/ha which significantly increased plant characteristics such as number of fruits per plant, length and size of fruit medium, number of seeds per fruit and fruit yield. For example, the number of fruits per plant increased from 4.3 kg/ha in the control treatment to 8.2 kg/ha, but the yield of fruits between fertilizer treatments 300 kg/ha (26.88 t/ha) and 400 kg / ha (28.78 kg) was not significant. Finally, the best NPK fertilizer was obtained in the treatment of 300 kg/ha and the highest yield at planting time was obtained six weeks after planting.

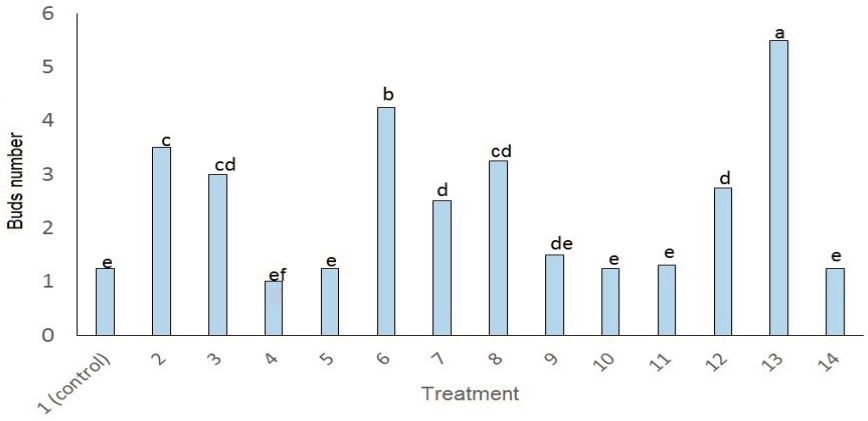

Fig. 6. Effect of different fertilization methods on the number of buds.

In another experiment, the effect of different levels of foliar application of zinc (0, 10, 20 and 30 mg/l) and soil application of potassium (60, 90, 120 and 150 kg/ha) from a source of 48% potassium sulfate on the quantitative and qualitative characteristics of sweet potatoes was investigated. It was reported that the highest yield compared to other treatments occurred at high levels of zinc foliar application and soil potassium application (El-baky *et al*., 2010). Dalal and Nandkar (2011) reported the best NPK values on cabbage (*Brassica juncea* L.var. Pusa) yield of 25-40-50 kg/ha, but when this value reached 35-50-70 kg/ha, there was a significant decrease in plant characteristics such as height and number of ovaries. Application of 120 kg/ha of potassium in corn fields of warm regions of South Asia increased the growth parameters and improved the grain quality of this plant (Sangakkara *et al*., 2011). Wang and Chen (2010) showed the best NPK ratio on whiteberry characteristics such as branch size, number of leaves in spring and their effect on silkworm and cocoon production in ratios 5-5-10.

Number and diameter of flowers

The effect of fertilizer treatments on the number and diameter of flowers can be seen in table 3. Due to the effect of fertilizer treatments on vegetative growth and later entry into the reproductive phase, which can be due to the type of variety used marigold, many flower buds are not open and therefore the criterion of this study is based on growth indices. It has a growth rather than reproductive indicators, especially flowers (Fig. 7).

Fig. 7. Comparison of plant height and flower diameter in some fertilization treatments (The treatment number 6 has been labelled by number 5).

Stem diameter

Fig. 8 shows the effect of fertilizer treatments on stem diameter. The trend of plant height was also observed approximately in the diameter of the stem. The largest stem diameter was observed in fertilizer treatment number six (although in the photos this treatment is marked with label number 5). In Fig. 9, the image shows the difference in stem diameter of several treatments compared to the control.

Conover and Henny (1995) reported that anthuriums had the best qualitatively and quantitatively growth in pots with minimum N and P. Lamont *et al*. (1990) also reported the best ratio of nitrogen and potassium for the growth and yield of Christmas Bells in a ratio of 1 to 1.5. Ashoorzadeh *et al*. (2016) observed an increase in stem height and diameter of *Araucaria excelsa* with fertilization and foliar application of different fertilizers. Haghighi *et al.* (2011) tested the effect of different levels of N (100, 150, 200 and 250 kg/ha) and K (250, 300 and 350 kg/ha) on tobacco plants. The results showed that nitrogen, at the level of 250 kg/ha, increased plant yield in height, number and length of leaves, leaf petiole size, nicotine content and beginning and end

Table 3. The effect of frtilization treatments on flower number and diameter.

Treatment number	Flower number	Flower diameter (cm)
1 (control)	-	-
2	1	2.85
3	-	-
4	-	-
5	0.5	2.25
6	0.5	2.37
7	0.5	-
8	0.25	1.37
9	-	-
10	-	-
11	0.5	2.12
12	-	-
13	0.25	1
14	-	-

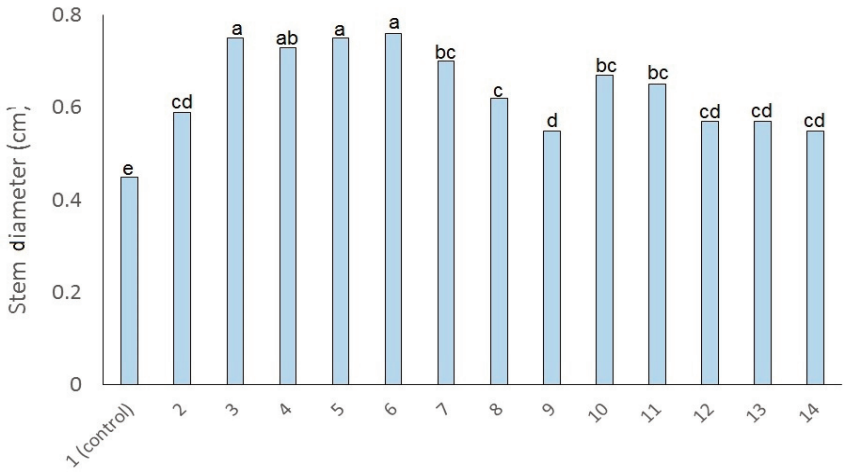

Fig. 8. Effect of different fertilization methods on the stem diameter.

Fig. 9. Comparison of plant height and stem diameter in treatments no. 4 and 13 in compare to control.

of flowering. Potassium at 350 kg/ha increased plant growth characteristics. The highest leaf fall was related to the treatment with a minimum amount of nitrogen of 150 kg/ha. But the effects of nitrogen and potassium interaction on plant yield were not significant.

Fresh and dry weight of shoot

Fig. 10 and 11 show the effect of fertilizer treatments on fresh and dry weight of shoots. The differences between the treatments under different fertilizer formulas and methods were clearly observed. In treatment number 6, the highest fresh weight of aerial parts was observed compared to control and other treatments. Fertilizer formulas at appropriate times and increase in nutrient uptake increased plant growth. Golcz *et al.* (2004) investigated the effects of two types of potassium fertilizers on red pepper. The used potassium fertilizers were potassium chloride and potassium sulfate in the ratio of 1: 1. The results showed that the concentration of elements in the leaves (N, Ca, Mg and Cl) decreased with the use of potassium sulfate fertilizer, but the two elements of potassium and sulfur increased in the leaves. While in fruits, the concentrations of potassium and sulfur increased with potassium chloride fertilizer.

Sajid *et al*. (2009) investigated the effect of foliar application of growth regulators and various nutrients required by the lily plant. In this experiment, foliar application of elements with potassium nitrate (19 mg/l), ammonia nitrate (16.5 mg/l), dihydro potassium phosphate (1.7 mg/l), calcium chloride (4.4 mg/l) and magnesium sulfate (3.7 mg/l). Gibberellic acid with a concentration of 20 mg/l was also selected from the hormones. The results showed that stem length increased by 25% compared to the control by foliar application of nutrients and the same index increased by 33% by foliar application of nutrients and hormones. In number of nodes and number of buds per stem, both treatments were much better than nutrient and control treatments.

Niaeifard and Tabatabai (2007) achieved important results on the optimal nutrition of cut lily flowers with nitrogen and potassium. They applied nitrogen at four levels (400-300-200-100 mg/l) and potassium at two levels of 200 and 100 mg/l, and found the best results with nitrogen 400 and potassium 200 mg/l treatment. Aslam Khan (2004) after studying the effect of different levels of NPK on the growth and flowering characteristics of gladiolus cultivar Wendsang, concluded that the amount of appropriate phosphorus and potassium and high nitrogen application, vegetative growth indicators such as height, number leaves increase leaf length and spike length. While a moderate amount of these three elements has a positive effect on flowering characteristics

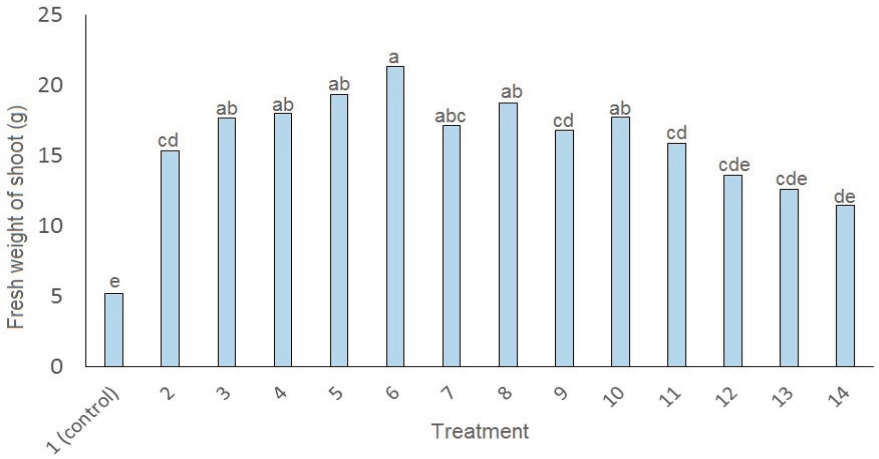

Fig. 10. Effect of different fertilization methods on the shoot fresh weight.

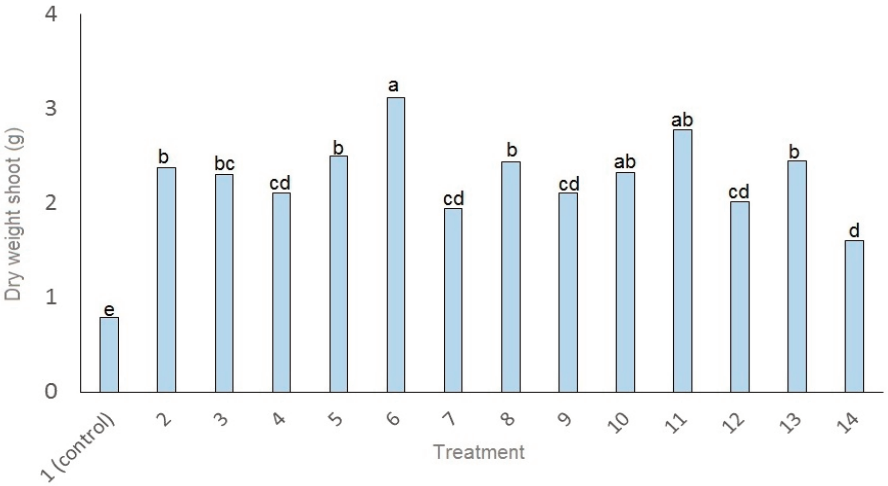

Fig. 11. Effect of different fertilization methods on the shoot dry weight.

and bulb development such as the appearance of spikes, opening of the first and last florets, bulb weight and diameter.

CONCLUSIONS

Overall results showed that different fertilization methods and different fertilizer formulas had a positive effect on plant growth compared to the control. Changes in plant growth were significant compared to the control and in fertilization methods and formulas. The best effect on plant growth was seen in treatment number 6 and this treatment is recommended for the growth of this variety of marigold. In this treatment, in the fourth week of planting seedlings from the first formula including the base ratio of nitrogen, phosphorus and potassium, 15-10-15 and in the fifth and sixth weeks of the second formula including the ratio of base nitrogen, phosphorus and potassium, 15-20-30, was used. It is suggested that in a long period of time, the effect of these formulas on vegetative and reproductive growth be investigated separately. It is suggested to study the state of nutrient uptake and resistance to drought and salinity stresses in the same fertilizer formulas or new methods.

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