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The Effect of Phosphorus on the Growth and Productivity of Mexican Marigold (*Tagetes minuta* L.)

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Abstract

Field trials were carried out in Sadra town near Shiraz, Iran in 2010 to determine the effect of phosphorus (P) on the productivity of Mexican Marigold (*Tagetes minuta* L.), an important medicinal plant. Phosphorus was band-placed at the rates of 0, 40, 80 and 120 Kg/ha at planting time. Results indicated that growth parameters and essential oil concentration increased with increasing the P levels. Application of 120 kg/ha P significantly increased the fresh and dry weights, plant height and flower numbers per plant. All P as compared with the control significantly enhanced the essential oil concentration. Moreover the role of phosphorus as a central and pivotal metabolic and regulatory nutrient element has been discussed.

Keywords: Mexican Marigold; phosphorus; essential oil; growth parameters.

Introduction

Asteraceae is the largest family of vascular plants with more than 23,000 species, rich in secondary metabolites and essential oils (EOs) (Negahban *et al.,* 2013). The genus *Tagetes*, with the common name of marigold, consists of 30-40 species that are endemic from Arizona to Argentina (Sefidkon *et al.*, 2004). Mexican marigold (*Tagetes minuta* L.) is an annual plant belongs to the Asteraceae family. It is native of grasslands and mountainous regions of South America including Argentina, Chile, Bolivia, Peru, and in the Chaco region of Paraguay (Negahban *et al.,* 2013). *T. minuta* grows wild from spring to early winter when it completes its life cycle (Babu and Kaul 2007).

Tagetes minuta L., a species native to southern South America, is used as a condiment, as a refreshing beverage, and for medicinal purposes.In recent years, there has been an increasing interest in using the herbal products of indigenous peoples. *Tagetes minuta* could be another new herb brought to the world market (Meshkatalsadat *et al.,* 2010).*Tagetes minuta* is commercially grown and harvested for its essential oils which are used in the flavor and perfume industry as "Tagetes Oil." The oil is used in perfumes, and as a flavor component in most major food products, including cola beverages, alcoholic beverages, frozen dairy desserts, candy, baked goods, gelatins, puddings, condiments, and relishes (Meshkatalsadat *et al.,* 2010).

Tagetes EO is used to treat chest infections, coughs and catarrh, dilating bronchi, facilitating the flow of mucus and dislodging congestion and can be used in cases of skin infections. It has a

healing effect on wounds, cuts, calluses and bunions (Negahban *et al.,* 2013, Meshkatalsadat *et al.* 2010).

In commercial medicinal plant production, the main objective is to produce high biomass yields per hectare with high levels of secondary metabolites. Nutritional requirements have a major effect on the yield and growth of all horticultural and agronomic crops (Saharkhiz and Omidbaigi, 2008). On the other hand the level of secondary metabolites in medicinal plants may be positively or negatively affected by the kind and amount of nutrient elements. Phosphate plays a central, pivotal metabolic and regulatory role on the nexus of several physiological and biochemical processes in plants, including photosynthesis, energy conservation, inter- and intracellular co-ordination of carbohydrate metabolism (Abel, 2002) and in energy transfer (Saharkhiz and Omidbaigi 2008).

Trivino and Johnson, (2000) have reported that total yield of volatile oil of (*Origanum majorana* L.) was increased by 50% as P was increased up to 3.0 mM in soil solution (Trivino and Johnson, 2000). Moreover, the fresh and dry weights were increased two-fold by P treatment as compared to the control. Ichimura *et al*., (1995) observed that P significantly increased the fresh weight and essential oil concentration in Sweet basil (Ichimura *et al*., 1995). Similar results have been noted with black cumin (*Nigella sativa*) and coriander (*Corianderum sativum*) by several workers. (Das *et al*., 1991; Ughreja and Chundawat, 1992). The main objective of present study was to investigate the effects of different P levels on the yield and essential oil concentration of *Tagetes minuta* L.

Materials and Methods

Plant Material

The seeds of Mexican Marigold were provided by Zardband Pharmaceutical Company located in Tehran, Iran. The seeds were cultivated in Sadra town (Shiraz, Iran) in February 2010. Plants were grown in sandy loam soil. Some of the physiological characteristics of the soil are shown in Table 1. The experiment was arranged as a randomized completely block design (RCBD) with four replications. The treatment consisted of 4 phosphorus levels (0, 40, 80, 120 kg ha^{-1}) as triple super phosphate.

Phosphorus was band-placed in two rows, 100 mm deep and 150 mm apart at each site. The seedlings of equal height and vigour were hand transplanted from the nursery bed to the field in mid-April. Each plot was of 2 m^2. The seedlings were planted between the fertilizer bands in rows, 30 cm apart and there was 20 cm distance between every plant. All plots were furrow irrigated immediately after transferring the seedlings to the field.

Irrigation was carried out every day for one week to establish the seedlings in soil. Hoeing and mechanical weeding were done as needed.

Plant height, flower numbers per plant, chlorophyll content, shoot fresh and dry weight were measured at the full flowering stage.

Large foliar stalks were harvested with pruning-shears, leaving about 5 cm above the ground surface. The shoots and roots fresh weight and flower number were measured.

All samples were shade-dried (during 15 days). EO was extracted by subjecting flowers and leaves together (50 g) to hydrodistillation for 2 h using an all glass Clevenger-type apparatus (Goldis, Tehran, Iran), according to the method outlined by the European pharmacopoeia (Anonymous 1996). EO yield was expressed as percentage w/w on dry matter basis. The oils were dried over anhydrous Na_2SO_4 and stored in sealed vials at low temperature (4°C) before analysis. Data were subjected to variance analysis and means were compared by using Duncan's New Multple Range Test (DNMRT).

Table 1: Some physical and chemical characteristics of the experimental soil

EC ds m^{-1}	pH	OC[a] (%)	TN[b] (%)	P (mg kg^{-1})	K(mg kg^{-1})	Silt (%)	Sand (%)	Clay (%)
1.8	7.8	1.775	0.06	14	275	12	78	10

[a] Organic matter (OC), [b] Total Nitrogen (TN)

Results and Discussion

The statistical analysis showed that plant height, flower numbers per plant, fresh and dry weights and essential oil concentration increased significantly by soil P application as compared to control ($P \leq 0.05$).

The data demonstrated that soil P fertilization had a significant effect on the plant height, flower numbers per plant, fresh weigh, dry weight and essential oil concentration with respect to control (Figures 1, 2, 4, 5, 6). However, dry weight significantly increased with increasing P level up to 120 kg /ha (Fig 5). Chlorophyll content decreased with increasing P level up to 80 kg /ha. However, it increased significantly in 120 kg /ha (Fig 3).

No further response was obtained with higher P rate. In the present study, the lowest and highest amounts of essential oil was recorded with 0 and 120kg P/ha^{-1} respectively.

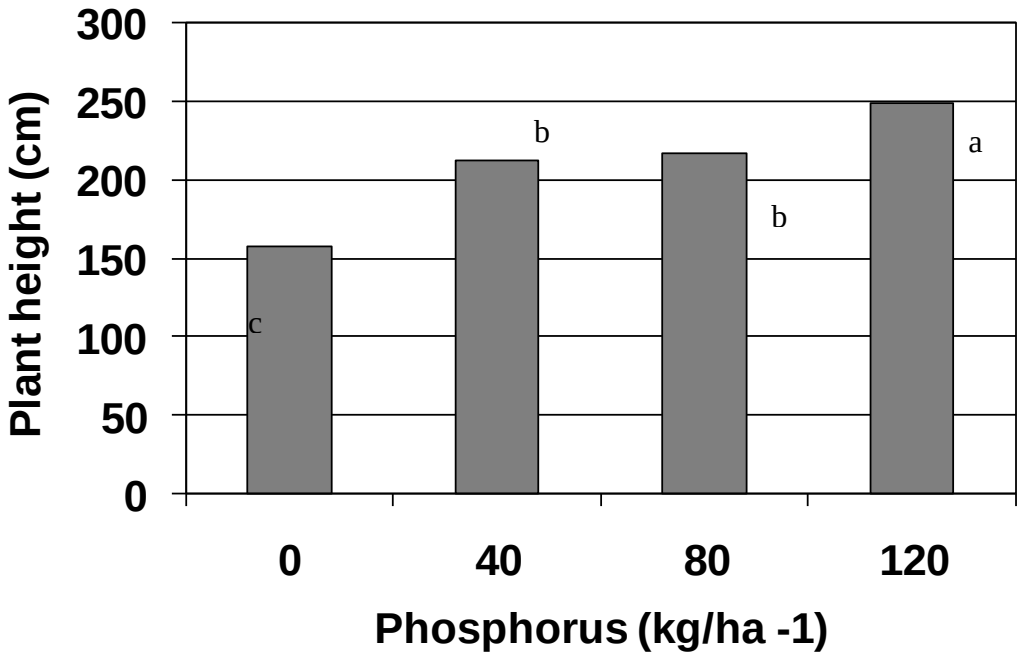

Fig. 1: Effect of phosphorus on the plant height of *Tagetes minuta* L. at $P \leq 0.05$. Means followed by the same letter are not significantly different, as indicated by DNMRT.

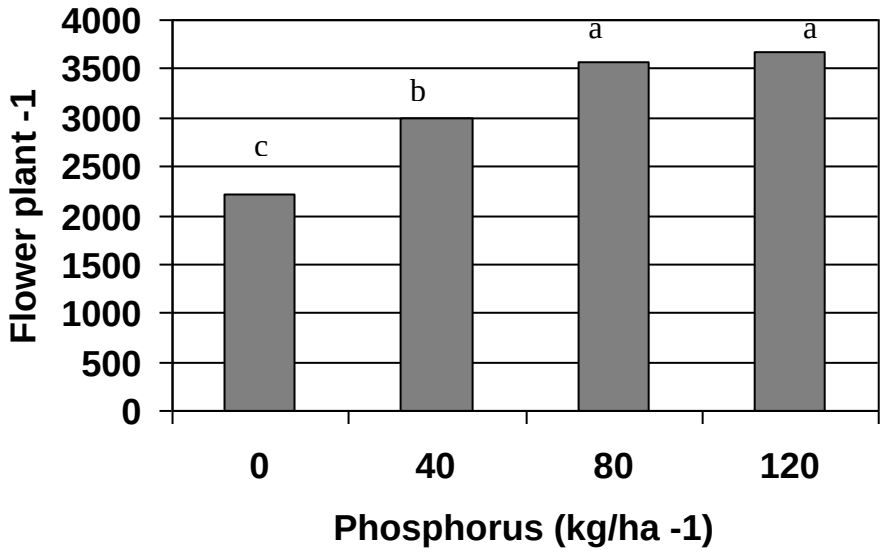

Fig. 2: Effect of phosphorus on the flower numbers of *Tagetes minuta* L. at $P \leq 0.05$. Means followed by the same letter are not significantly different, as indicated by DNMRT.

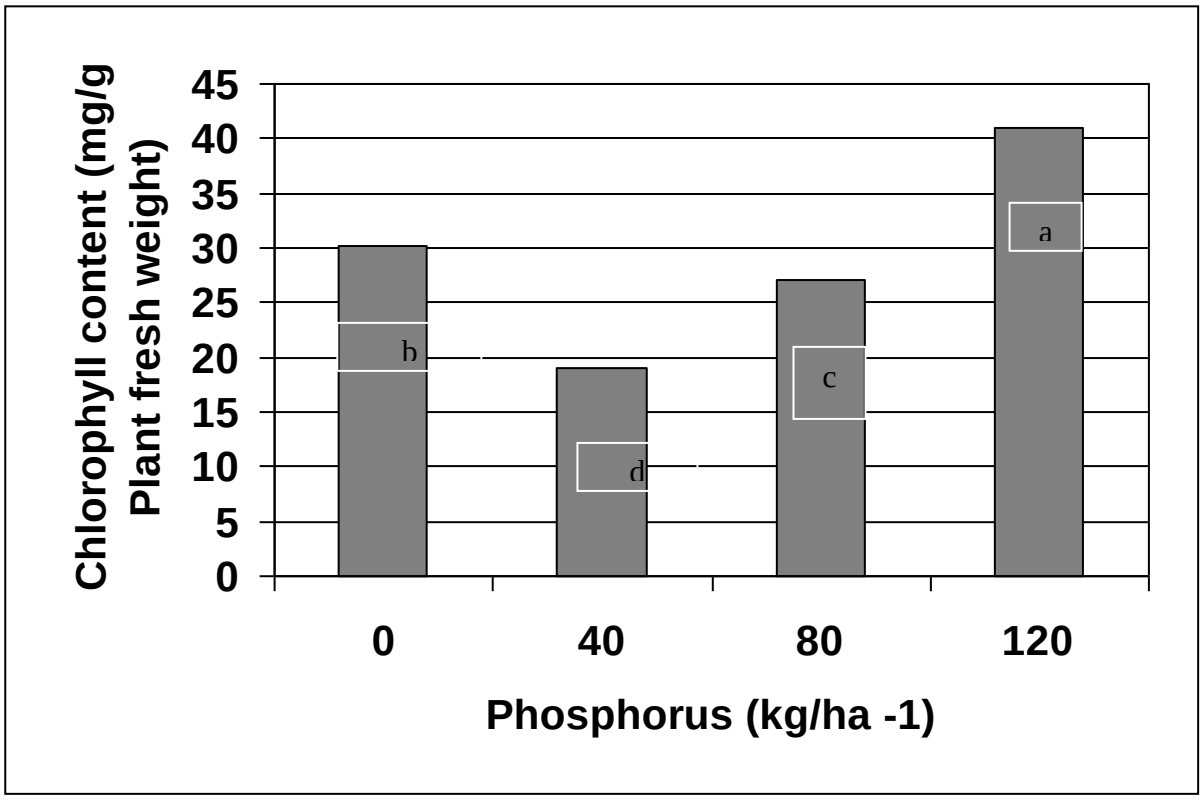

Fig. 3: Effect of phosphorus on the chlorophyll content of *Tagetes minuta* L. at $P \leq 0.05$. Means followed by the same letter are not significantly different, as indicated by DNMRT.

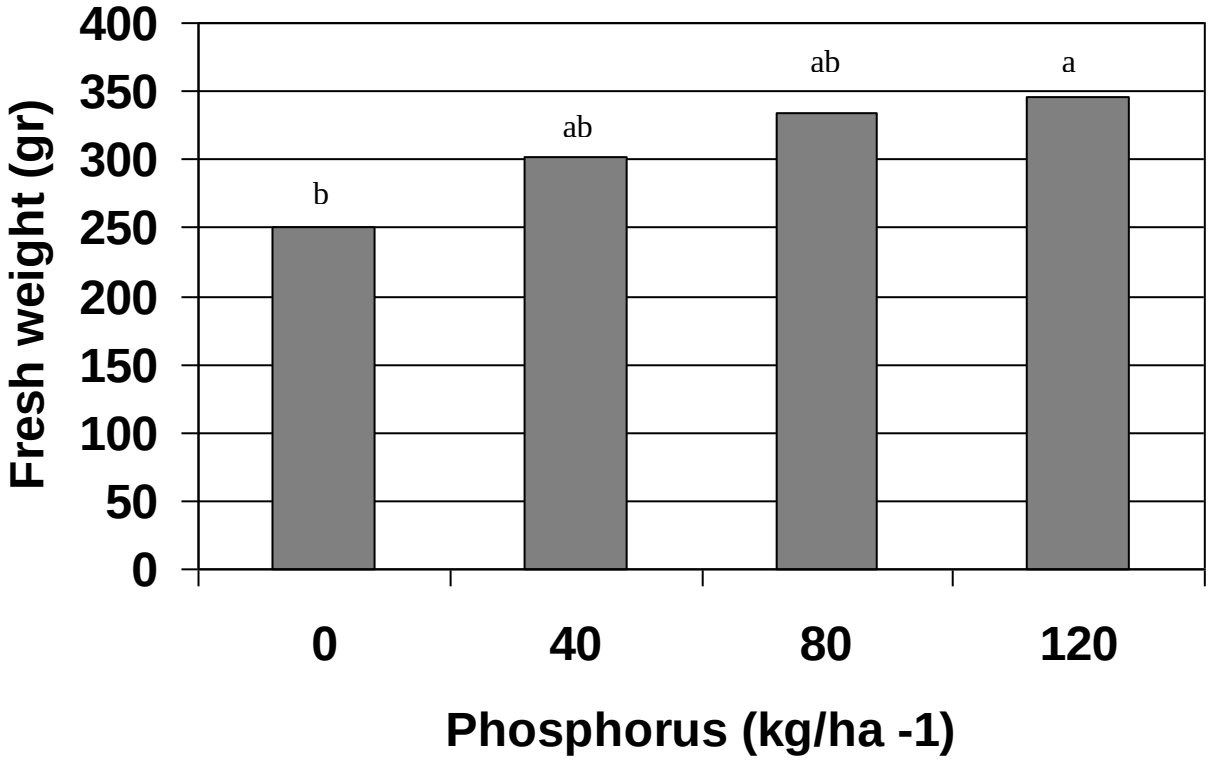

Fig. 4: Effect of phosphorus on the fresh weight of *Tagetes minuta* L. at $P \leq 0.05$. Means followed by the same letter are not significantly different, as indicated by DNMRT.

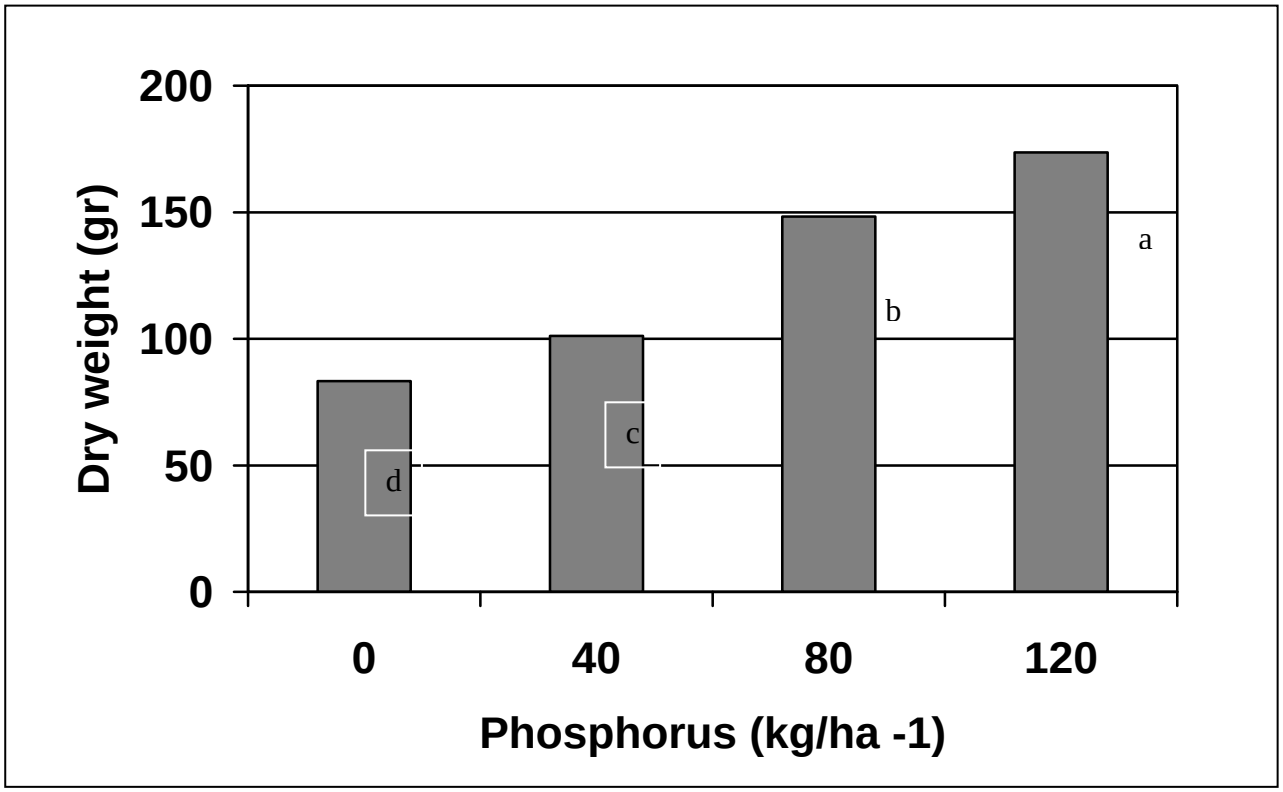

Fig. 5: Effect of phosphorus on the dry weight of *Tagetes minuta* L. at $P \leq 0.05$. Means followed by the same letter are not significantly different, as indicated by DNMRT.

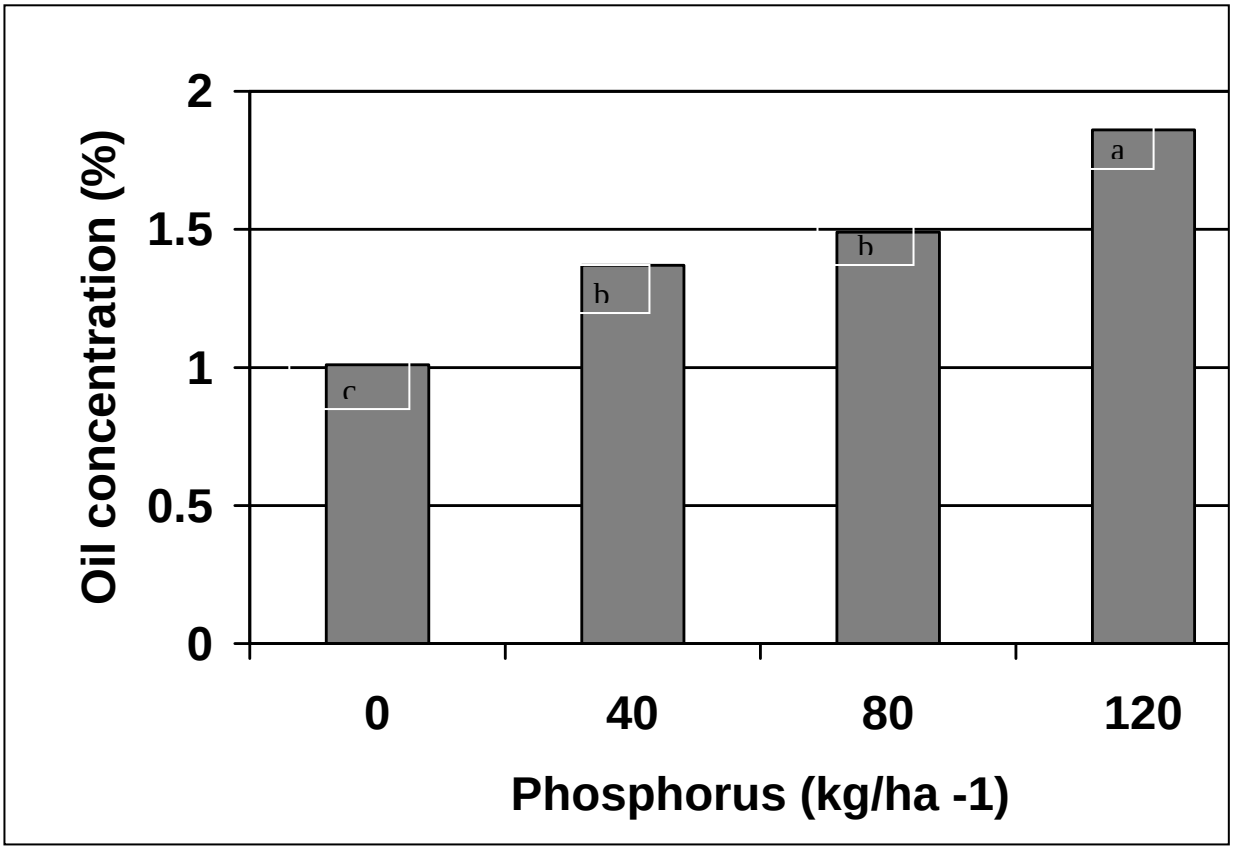

Fig. 6: Effect of phosphorus on the essential oil concentration of *Tagetes minuta* L. at $P \leq 0.05$. Means followed by the same letter are not significantly different, as indicated by DNMRT.

The data of this investigation showed that all growth parameters ,except chlorophyll content, were positively affected by phosphorus application. Phosphorus significantly increased fresh and dry matter, flower numbers, plant height and essential oil concentration. The total dry matter is an important criterion for crop production. The most effective P rate was 120 kg/ha and increasing the amount of phosphorous to 120 kg/ha did not significantly affect either the morphological characteristics or essential oil concentration in Mexican Marigold. These results are similar to those of Salardini *et al*., (1994) and Saharkhiz and Omidbaigi (2008) with pyrethrum (*Tanacetum cinerariifolium*) who reported that application of 100 kg P/ha significantly increased achenes and pyrethrin yield for this crop (Salardini *et al*., 1994). They are also in agreement with the data of Nikolova *et al*., (1999) who showed P fertilization increased the essential oil concentration of chamomile (Nikolova *et al*., 1999) and with Nilbe *et al*., (2005) who observed increasing biomass of chamomile (Nilbe *et al*., 2005). It is well documented that phosphorus is an essential element in reproductive and vegetative growth of plants (Marschner, 1986) and thus, the vegetative growth and flower numbers stimulation and increased by applied P was expected in our study. Phosphorus is also known to have multifarious cellular functions in plants, including: signalling and transmembrane metabolic flux and therefore, the secondary metabolism is modulated by these mechanisms (Ram *et al*., 2003). In conclusion, it appears that P is a crucial nutrient element for Mexican Marigold cultivation. Therefore, it is strongly recommended that on sites low in available P, the crop be supplied with adequate P. Furthermore, the authors suggest that the influence of P soil addition on the growth, chemical composition and biochemical indices of Mexican Marigold be thoroughly studied on locations with wide range of climatology, physical and chemical properties and mineralogical characteristics.

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