Research Article

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# Fertilization enhances growth, yield, and xanthophyll contents of marigold

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**Abstract:** The effects of various NPK levels on growth, flowering, and xanthophyll contents of African marigold (*Tagetes erecta,* 'Double Eagle') and French marigold (*Tagetes patula,* 'Yellow') were investigated. Plant height, number of branches plant$^{-1}$, leaf area (cm$^2$), total chlorophyll contents (mg g$^{-1}$), number of flowers plant$^{-1}$, flower diameter, flower quality, fresh and dry weight of a flower, total flower weight plant$^{-1}$, blooming period, and days to flowering were maximum with 15:10:10 g m$^{-2}$ NPK application. However, leaf nitrogen, phosphorus, and potassium contents reached the highest values with 15:20:10, 5:20:10, and 10:20:10 g m$^{-2}$ NPK application, respectively. Xanthophyll contents were higher in plants fertilized with 15:20:10 g m$^{-2}$ NPK application. Results suggested that NPK fertilization enhanced growth and improved yield, quality, and xanthophyll contents of marigold.

**Key words:** Annual flowers, lutein, macronutrients, specialty cut flowers, *Tagetes* spp.

## Introduction

Marigold, a member of the family *Asteraceae* or *Compositae*, is a potential commercial flower that is gaining popularity on account of its easy culture, wide adaptability, and increasing demand in the subcontinent (Asif 2008). Marigold is grown as an ornamental crop for its flowers, which are sold in the market as loose flowers in bulk, as specialty cut flowers, or for making garlands. It is also one of the most important natural sources of xanthophylls for use as natural food additive to brighten egg yolks and poultry skin (Bosma et al. 2003). Moreover, it is also being used effectively to dye fabrics commercially, where its ethanol-based flower extracts produce different colors on fabrics (Vankar et al. 2009). Deineka et al. (2007) have reported that marigold cultivars with orange color flowers have higher xanthophylls as compared with yellow. Lutein ($C_{40}H_{56}O_2$) is the primary xanthophyll pigment that produces the orange color in marigold flower, comprising 90% of the petals identified pigments (Quackenbush and Miller 1972). This lutein, having antioxidant properties, is also useful in eye health protection (Vankar et al. 2009). Marigold has been most commonly used by the poultry industry to augment the xanthophyll present in corn and alfalfa feed to standardize the feed's xanthophyll contents (Delgado-Vergas et al. 1998).

Proper combination of fertilizers plays a vital role in production of vigorous plants having maximum number of shoots and leaves, which have a positive impact on quality flower production and prolonged flowering period. Optimum cultural practices are necessary for quality flower production. Among

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essential nutrients, nitrogen, phosphorus, and potassium are most important for plant growth and flowering. These also play a key role in the production of higher flower and seed yield of ornamentals (Kashif 2001). These also enhance the vegetative growth and assist the plant during the blooming period to mobilize the process of flower opening. Flowering can be increased with increased levels of NPK application (Anamika and Lavania 1990). In marigold, plant vigor was decreased as the season progressed, which was attributed to nitrogen deficiency. Moreover, pigment yield was increased to the maximum by 3 nitrogen applications in a single season (Baldwin et al. 1993). On the other hand, excessive nitrogen fertilization may result in lush growth and subsequently increased insect damage and disease problems (Agrios 1997).

At industrial level, most egg producers use a high energy concentrated feed having a low pigment content, which must be supplemented with natural pigments. This supplementation should consider people's concerns and governmental regulations preventing addition of synthetic pigments. Some of the traditional sources of natural xanthophylls are yellow corn, alfalfa, and marigold (Asif 2008). Potential of many floricultural crops has yet not been explored to maximum in Pakistan and most of our high valuable flower crops are grown in flowering beds only for ornamental purposes. Moreover, studies have been conducted on varietal estimation of xanthophyll production but no significant effect of fertilization has been reported. Therefore, this study was conducted to explore their potential for value addition. The specific objective of this study was to find out optimum level of NPK fertilization in proper combination to get healthy and vigorous plant growth, maximum flower production of superior quality, and higher xanthophyll contents in marigold petals.

## Materials and methods

Two marigold cultivars, viz. African marigold (*Tagetes erecta,* 'Double Eagle') and French marigold (*Tagetes patula,* 'Yellow'), were grown at the Institute of Horticultural Sciences, University of Agriculture, Faisalabad, on separate plots containing soil, silt, and organic manure (1:1:1). After nursery raising in a greenhouse, 4-week-old seedlings at 2-3 true leaf stage were transplanted in field plots at 30 cm distance in 30 cm spaced rows. Treatments were set in a randomized complete block design with factorial arrangements. There were 9 fertilizer treatments with 3 replicates applied to both cultivars and 10 seedlings were transplanted in each replicate. Fertilizer sources for N, P, and K elements constituted urea (46% N), single superphosphate (18% $P_2O_5$), and muriate of potash (50% $K_2O$), respectively. Nitrogenous and phosphatic fertilizers were applied at various levels while potash was applied at a constant rate of 10 g $m^{-2}$. Levels of nitrogen were 5 g, 10 g, and 15 g $m^{-2}$ whereas those of phosphorus were 10 g and 20 g $m^{-2}$. Treatment combinations were 0:0:0 g $m^{-2}$ NPK (control), 0:10:10 g $m^{-2}$, 0:20:10 g $m^{-2}$, 5:10:10 g $m^{-2}$, 5:20:10 g $m^{-2}$, 10:10:10 g $m^{-2}$, 10:20:10 g $m^{-2}$, 15:10:10 g $m^{-2}$, and 15:20:10 g $m^{-2}$ NPK. Fertilizer treatments with half dose of nitrogen and complete dose of phosphorus and potash were applied according to treatments at transplanting, while the other half dose of nitrogen was applied 30 days after transplanting. All fertilizers were broadcasted uniformly in the plots and thoroughly mixed in the soil followed by irrigation after transplanting. Subsequent irrigations were applied when needed depending upon climatic conditions, rate of precipitation, and rate of usage. All other cultural practices, e.g., weeding, hoeing, staking, and IPM, were kept similar for all treatments during the entire period of the study. Data were collected at harvest for plant height (cm), number of branches $plant^{-1}$, leaf area ($cm^2$), days to flowering, number of flowers $plant^{-1}$, flower diameter (cm), fresh and dry weight of a flower (g), and flower quality (Cooper and Spokas 1991). Total flower weight $plant^{-1}$ and blooming period (day) were recorded at the end of the harvest season. Leaf samples were collected at the start of flowering to determine leaf nitrogen (Lierop 1976), and phosphorus and potassium contents (%) and flower xanthophylls contents (mg $g^{-1}$) were estimated on a spectrophotometer by using a standard curve (AOAC, 1984). Data were analyzed statistically by following Fisher's analysis of variance and treatment means were compared using Tukey's test at $P \leq 0.05$ (Steel et al. 1997).

## Results

### Effect of NPK on growth

For African marigold, 15:10:10 g $m^{-2}$ NPK application produced taller (128.5 cm) plants followed by 15:20:10 g $m^{-2}$ NPK (122.8 cm), while unfertilized plants (control) produced shorter (80.7 cm) plants (Table 1). Regarding French marigold, 10:10:10 g $m^{-2}$ NPK resulted in taller plants with 64.6 cm height followed by 5:20:10 and 5:10:10 g $m^{-2}$ NPK (64.0 and 63.4 cm, respectively) and were statistically at par while no fertilization produced dwarf plants (39.5 cm). For number of branches $plant^{-1}$, 15:10:10 g $m^{-2}$ NPK produced more branches $plant^{-1}$ (30.1) in African marigold followed by 10:20:10, 15:20:10, and 10:10:10 g $m^{-2}$ NPK (29.7, 29.0, and 27.9, respectively) and were statistically similar, while unfertilized plants (control) had minimum branches $plant^{-1}$ (19.3) (Table 1). For French marigold, plants supplied with 10:10:10 g $m^{-2}$ NPK produced maximum branches $plant^{-1}$ (20.4), while unfertilized ones had minimum branches (14.5).

In African marigold, maximum leaf area was recorded with 15:10:10 g $m^{-2}$ NPK application (29.30 $cm^2$) followed by 15:20:10 and 10:20:10 g $m^{-2}$ NPK (28.70 $cm^2$ each) and were statistically similar, while unfertilized plants had minimum leaf area (16.3 $cm^2$) (Table 1). In French marigold, higher leaf area was observed with higher fertilization levels, viz. 10:20:10, 10:10:10, 15:10:10, and 15:20:10 g $m^{-2}$ NPK application (18.70, 18.30, 18.00, and 17.70 $cm^2$, respectively) and were statistically at par, while minimum leaf area was recorded in unfertilized plants (10.00 $cm^2$). In African marigold, plants supplied with higher N levels, viz. 15:10:10 and 15:20:10 g $m^{-2}$

Table 1. Vegetative growth of marigold as influenced by various combinations of NPK.

| | Plant height (cm) | | Number of branches $plant^{-1}$ | | Leaf area ($cm^2$) | | Total leaf chlorophyll contents (mg $g^{-1}$ FW) | |
|---|---|---|---|---|---|---|---|---|
| | African marigold | French marigold | African marigold | French marigold | African marigold | French marigold | African marigold | French marigold |
| Control | 80.7 e | 39.5 c | 19.3 c | 14.5 b | 16.30 c | 10.00 d | 0.7 c | 1.5 b |
| 0:10:10 g $m^{-2}$ NPK | 95.5 d | 54.0 b | 24.5 b | 17.6 ab | 18.70 b | 13.00 c | 0.7 c | 1.9 a |
| 0:20:10 g $m^{-2}$ NPK | 97.0 d | 57.4 b | 24.5 b | 18.7 a | 18.70 b | 14.00 bc | 0.7 c | 1.9 a |
| 5:10:10 g $m^{-2}$ NPK | 99.1 d | 63.4 a | 24.8 b | 18.7 a | 19.70 b | 15.00 b | 0.8 b | 2.1 a |
| 5:20:10 g $m^{-2}$ NPK | 107.0 c | 64.0 a | 27.4 b | 19.2 a | 21.70 b | 17.30 a | 0.8 b | 2.2 a |
| 10:10:10 g $m^{-2}$ NPK | 107.4 c | 64.6 a | 27.9 ab | 20.4 a | 28.00 a | 18.30 a | 0.8 b | 2.2 a |
| 10:20:10 g $m^{-2}$ NPK | 115.1 b | 58.5 b | 29.7 ab | 16.2 ab | 28.70 a | 18.70 a | 0.9 ab | 2.2 a |
| 15:10:10 g $m^{-2}$ NPK | 128.5 a | 58.2 b | 30.1 a | 18.3 a | 29.30 a | 18.00 a | 1.0 a | 2.1 a |
| 15:20:10 g $m^{-2}$ NPK | 122.8 ab | 59.5 b | 29.0 ab | 17.6 ab | 28.70 a | 17.70 a | 1.0 a | 2.0 a |

Means followed by same letter in a column are not significantly different at $P \leq 0.05$.

NPK, had higher leaf chlorophyll contents (1.0 mg $g^{-1}$ FW) followed by 10:20:10 g $m^{-2}$ NPK (0.9 mg $g^{-1}$ FW), whereas unfertilized plants and those without N application had minimum leaf chlorophyll contents (0.7 mg $g^{-1}$ each) (Table 1). In French marigold, all NPK applications produced statistically similar leaf chlorophyll contents, while unfertilized plants had minimum leaf chlorophyll contents (1.5 mg $g^{-1}$ FW).

**Effect of NPK on flower yield and quality**

For days to flowering, 15:20:10 and 15:10:10 g $m^{-2}$ NPK application produced early flowering after 45.7 and 46.0 days, respectively, in African marigold, whereas unfertilization (control) started flowering late after 62.7 days (Table 2). In French marigold, early flowering was observed with higher N applications, viz. 15:10:10 and 15:20:10 (46.7 and 47.7 days, respectively), while unfertilized plants delayed flowering until 58.3 days. In African marigold, maximum flowers $plant^{-1}$ were recorded in 15:10:10 g $m^{-2}$ NPK (59.0), while minimum flowers $plant^{-1}$ (35.0) were produced in unfertilized plants (Table 2). For French marigold, maximum flowers were recorded in plants supplied with 15:20:10 g $m^{-2}$ NPK application (78.5), while minimum flowers $plant^{-1}$ were recorded in unfertilized plants (38.2).

Higher concentration of N application produced flowers with larger diameter (6.9 and 6.8 cm) in African marigold with minimum diameter in unfertilized ones (4.8 cm) (Table 2). In French marigold, fertilized plants had higher flower diameter as compared with unfertilized plants (control) (2.7 cm). The best quality flowers were produced by plants fertilized with higher N concentration (8.0) in African marigold, while unfertilized plants had average quality blooms (5.9) (Table 2). In French marigold, the best flower quality was observed

Table 2. Flower yield and quality of marigold as influenced by various combinations of NPK.

| | Days to first flower | | Number of flowers $plant^{-1}$ | | Flower diameter (cm) | | Flower quality | |
|---|---|---|---|---|---|---|---|---|
| | African marigold | French marigold | African marigold | French marigold | African marigold | French marigold | African marigold | French marigold |
| Control | 62.7 a | 58.3 a | 35.0 d | 38.2 f | 4.8 d | 2.7 c | 5.9 c | 6.0 d |
| 0:10:10 g $m^{-2}$ NPK | 59.0 b | 56.7 b | 40.0 c | 48.0 e | 5.1 c | 2.9 bc | 6.0 bc | 6.2 c |
| 0:20:10 g $m^{-2}$ NPK | 55.7 c | 56.7 b | 47.0 bc | 56.5 d | 5.3 bc | 3.0 b | 6.3 b | 6.2 c |
| 5:10:10 g $m^{-2}$ NPK | 50.0 d | 56.3 b | 47.3 bc | 63.3 c | 5.3 bc | 3.2 a | 6.6 b | 6.5 bc |
| 5:20:10 g $m^{-2}$ NPK | 49.3 d | 53.3 bc | 48.3 b | 64.5 c | 5.8 b | 3.1 ab | 6.8 ab | 6.7 bc |
| 10:10:10 g $m^{-2}$ NPK | 49.0 d | 50.7 c | 48.5 b | 70.0 b | 6.2 ab | 3.2 a | 7.0 ab | 7.0 b |
| 10:20:10 g $m^{-2}$ NPK | 47.7 de | 49.3 c | 50.0 b | 70.0 b | 6.2 ab | 3.2 a | 7.4 ab | 7.6 a |
| 15:10:10 g $m^{-2}$ NPK | 46.0 e | 46.7 d | 59.0 a | 73.3 b | 6.9 a | 3.2 a | 8.0 a | 8.1 a |
| 15:20:10 g $m^{-2}$ NPK | 45.7 e | 47.7 cd | 56.4 a | 78.5 a | 6.8 a | 3.2 a | 7.7 a | 7.9 a |

Means followed by same letter in a column are not significantly different at $P \leq 0.05$.

with 15:10:10 g m$^{-2}$ NPK application (8.1) followed by 15:20:10 and 10:20:10 g m$^{-2}$ NPK (7.9 and 7.6, respectively) and were statistically similar, while average quality blooms were recorded in unfertilized plants.

**Effect of NPK on flower weight and blooming period**

In African marigold, higher fresh weight of a flower was recorded with 15:10:10 g m$^{-2}$ NPK application (11.0 g) followed by 10:10:10 and 10:20:10 g m$^{-2}$ NPK (10.0 g each) and were statistically similar, while unfertilized plants (control) had minimum fresh flower weight (7.8 g) (Table 3). In French marigold, higher fresh weight of a flower was recorded with 15:20:10 g m$^{-2}$ NPK application (1.9 g), while unfertilized plants had minimum fresh weight (1.4 g). Higher dry weight of a flower was observed in plants fertilized with 15:10:10 g m$^{-2}$ NPK (1.92 g) in African marigold followed by 15:20:10, 10:20:10, and 10:10:10 g m$^{-2}$ NPK (1.91, 1.89 and 1.84 g, respectively) and were statistically at par, while unfertilized plants (control) had minimum dry weight of a flower (1.25 g) (Table 3). In French marigold, higher dry weight of a flower was recorded with 15:20:10 g m$^{-2}$ NPK application (0.41 g), while unfertilized plants and the ones with no N application had minimum dry weight of a flower (0.32, 0.32, and 0.33 g, respectively) and were statistically similar.

Higher flower weight plant$^{-1}$ was obtained in plants supplied with 15:10:10 and 15:20:10 g m$^{-2}$ NPK (496.1 and 473.9 g, respectively), while minimum flower weight plant$^{-1}$ was recorded in unfertilized plants (control) (210.5 g) in African marigold (Table 3). In French marigold, maximum flower weight plant$^{-1}$ was recorded in 15:20:10 and 15:10:10 g m$^{-2}$ NPK application (146.5 and 135.5 g, respectively), while minimum flower weight plant$^{-1}$ was observed in unfertilized plants (control) (57.5 g). Longer blooming period was observed in African marigold fertilized with 15:20:10 g m$^{-2}$ NPK application (87 days), while unfertilized plants (control) had a shorter blooming period (64 days). In French marigold, blooming period was longer with 15:10:10 and 15:20:10 g m$^{-2}$ NPK application (75 and 72 days, respectively) and were statistically similar, whereas unfertilized plants (control) stopped flowering earlier (54 days).

Table 3. Flower weight and blooming period of marigold as influenced by various combinations of NPK.

| | Fresh weight of flower (g flower$^{-1}$) | | Dry weight of flower (g flower$^{-1}$) | | Total flower weight (g plant$^{-1}$) | | Blooming period (days) | |
|---|---|---|---|---|---|---|---|---|
| | African marigold | French marigold | African marigold | French marigold | African marigold | French marigold | African marigold | French marigold |
| Control | 7.8 c | 1.4 b | 1.25 c | 0.32 b | 210.1 e | 57.5 f | 64.0 c | 54.0 d |
| 0:10:10 g m$^{-2}$ NPK | 9.4 ab | 1.5 b | 1.33 bc | 0.32 b | 247.8 d | 72.5 e | 70.0 b | 58.0 c |
| 0:20:10 g m$^{-2}$ NPK | 9.5 ab | 1.5 b | 1.42 b | 0.33 b | 279.0 c | 80.0 d | 70.0 b | 60.0 c |
| 5:10:10 g m$^{-2}$ NPK | 9.6 ab | 1.7 ab | 1.63 ab | 0.35 ab | 282.6 c | 95.0 c | 77.0 ab | 62.0 bc |
| 5:20:10 g m$^{-2}$ NPK | 9.6 ab | 1.7 ab | 1.75 ab | 0.36 ab | 288.7 c | 111.5 b | 78.0 ab | 67.0 b |
| 10:10:10 g m$^{-2}$ NPK | 10.0 a | 1.8 ab | 1.84 a | 0.37 ab | 391.9 b | 123.5 ab | 79.0 ab | 70.0 ab |
| 10:20:10 g m$^{-2}$ NPK | 10.0 a | 1.8 ab | 1.89 a | 0.38 ab | 413.0 ab | 125.0 ab | 80.0 ab | 70.0 ab |
| 15:10:10 g m$^{-2}$ NPK | 11.0 a | 1.8 ab | 1.92 a | 0.38 ab | 496.1 a | 135.5 a | 83.0 ab | 75.0 a |
| 15:20:10 g m$^{-2}$ NPK | 9.1 ab | 1.9 a | 1.91 a | 0.41 a | 473.9 a | 146.5 a | 87.0 a | 72.0 a |

Means followed by same letter in a column are not significantly different at $P \leq 0.05$.

**Effect of NPK on leaf NPK and flower xanthophylls contents**

Leaf analysis for nitrogen estimation in African marigold revealed higher N in plants fertilized with 15:10:10 and 15:20:10 g $m^{-2}$ NPK application (2.5% each) whereas unfertilized plants (control) had minimum N (1.7%) (Figure 1). In French marigold, 15:10:10 and 15:20:10 g $m^{-2}$ NPK application had higher N (2.6% each), whereas minimum N was recorded with no fertilization (control) (1.7%). Higher phosphorus was recorded in 15:20:10 g $m^{-2}$ NPK (0.59%) in African marigold, whereas minimum P was observed in unfertilized plants (control) (0.33%) (Figure 2). In French marigold, maximum phosphorus was recorded in plants fertilized with 5:20:10 and 0:20:10 g $m^{-2}$ NPK (0.42% and 0.40%, respectively), while those unfertilized had minimum phosphorus (0.27%).

In African marigold, higher K was recorded in plants fertilized with 5:20:10, 10:20:10 and 15:20:10 g $m^{-2}$ NPK application (2.87% each), while those without fertilization (control) had minimum K contents (2.79%) (Figure 3). In French marigold, maximum potash was recorded with 10:10:10 and 10:20:10 g $m^{-2}$ NPK application (2.97% each), while unfertilized ones (control) had minimum K (2.83%). In African marigold, higher xanthophyll contents were recorded in plants fertilized with 15:20:10 and 15:10:10 g $m^{-2}$ NPK (28.0 and 22.5 mg $g^{-1}$ FW, respectively) and were statistically similar, while unfertilized plants (control) produced minimum xanthophylls (5.1 mg $g^{-1}$ FW) (Figure 4). In French marigold, maximum xanthophylls were observed with 15:20:10 and 15:10:10 g $m^{-2}$ NPK (21.7 and 19.5 mg $g^{-1}$ FW, respectively), while minimum xanthophyll contents were recorded in unfertilized plants (2.4 mg $g^{-1}$ FW).

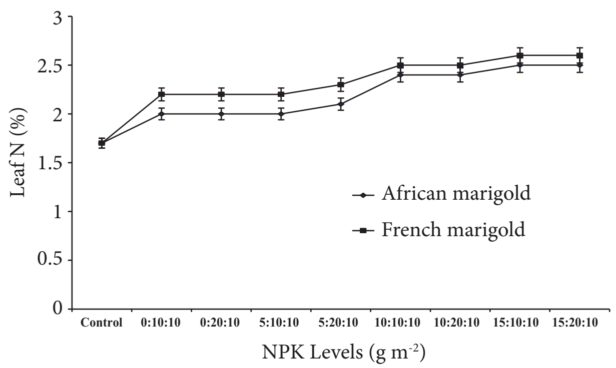


Figure 1. Leaf N (%) ± S.E. as influenced by various NPK levels at P ≤ 0.05.

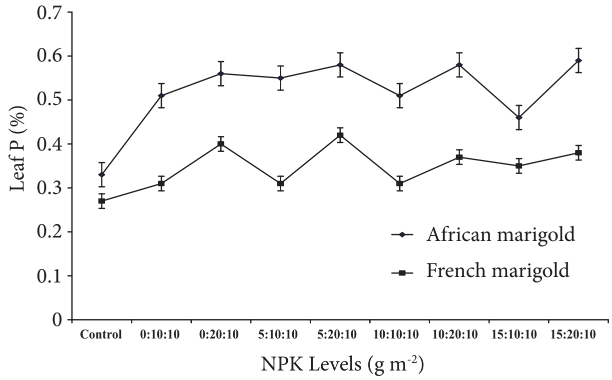


Figure 2. Leaf P (%) ± S.E. as influenced by various NPK levels at P ≤ 0.05.

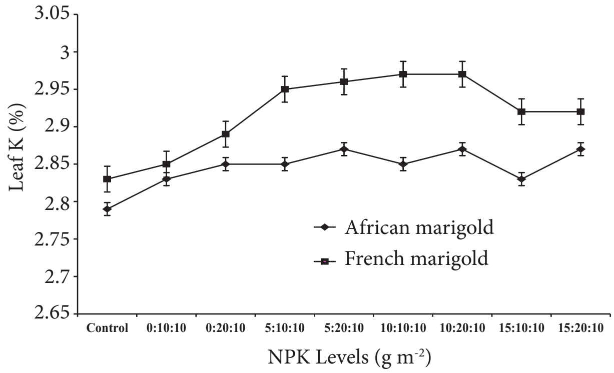


Figure 3. Leaf K (%) ± S.E. as influenced by various NPK levels at P ≤ 0.05.

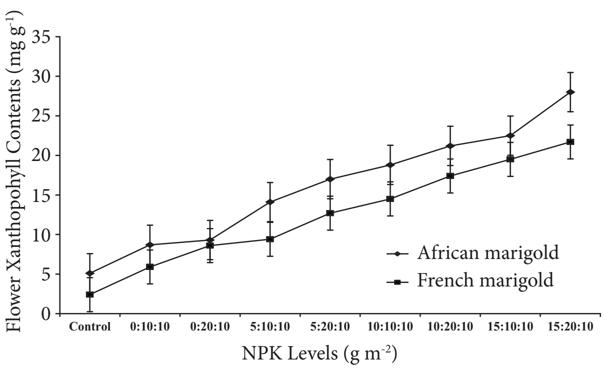


Figure 4. Flower xanthophyll contents (mg $g^{-1}$ FW) ± S.E. as influenced by various NPK levels at P ≤ 0.05.

## Discussion

Fertilization significantly improved the growth, yield, leaf nutritional status, and flower xanthophyll contents of marigold. The results revealed that higher N application rates expressed significant superiority over the rest of the treatments for improving growth of marigold, which is consistent with the findings of Arora and Singh (1980). Higher nitrogen and phosphorus application rates improved plant growth and yield. Leaf chlorophyll contents were higher with high N and P application, which is in confirmation with the findings of Rathore et al. (1985). Higher N application rate proved more effective for increasing flower yield and quality along with reducing the crop duration by early flowering particularly when associated with higher P and constant K application. These treatments helped plants to produce more photosynthates, which were used by plants for producing higher flower yield of good quality along with early production (Anuradha et al. 1990; Belorkar et al. 1992; Chadaha et al. 1999). A similar response was observed for fresh and dry weight of a flower, total flower yield plant$^{-1}$, and blooming period with the best results by higher N and P concentrations, which confirmed the positive effect of higher nitrogen and phosphorus application rate on reproductive growth of marigold (El-Saeid 1996; Chadaha et al. 1999; Khan et al. 2007).

Leaf nutrient analysis revealed higher nitrogen in plants fertilized with 15 g m$^{-2}$ (Nagaich et al. 2003; Lee et al. 2005; Khan et al. 2007). Maximum leaf phosphorus was observed in plants supplied with higher (20 g m$^{-2}$) level of P, which was in line with the findings of Lee et al. (2005) and Nagaich et al. (2003). Plants fertilized with higher P concentration also had higher K in their leaves, viz. 5:20:10 and 10:20:10 g m$^{-2}$ NPK (Nagaich et al. 2003; Khan et al. 2007). Plants supplied with a higher N rate produced higher flower xanthophyll contents, which revealed a positive correlation between nitrogen application and flower xanthophyll contents, which can be used to produce these xanthophylls for the poultry industry to reduce use of food crops for this purpose (Delgado-Vargas et al. 1998). These results are consistent with the findings of Baldwin et al. (1993), who reported increased pigment yield in marigold most with 3 applications of ammonium nitrate at the rate of 28 kg ha$^{-1}$ each, but are in contrast with those of Bosma et al. (2003), who reported no effect of N fertilization on xanthophyll contents. The results suggested that 15 g m$^{-2}$ N fertilization would help to increase growth and flower yield, which will enhance successful commercial marigold production. Among species, African marigold was the top producer in terms of growth, yield, flower weight, blooming period, and leaf nutrients as well as flower xanthophyll contents as compared with French marigold. These results are consistent with the findings of Deineka et al. (2007), who reported higher xanthophylls in orange color marigolds than yellow ones.

In summary, higher nitrogen and phosphorus application not only improved growth and production of best quality yield of marigold but also increased leaf nutrient status and flower xanthophyll contents. Moreover, African marigold is more suitable for commercial production on account of its higher yield and xanthophyll contents.

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