



Synergistic effect of nitrogen, phosphorus, potassium and zinc on ornamental sunflower (*Helianthus annuus* L.) CV. 'Ring of fire' as bedding plants

B Pamela Elisheba*, R Sudhagar

Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalai Nagar Chidambaram, Tamil Nadu, India

Abstract

The present study was carried out to standardize the nutrient requirement of ornamental sunflower used as bedding plants. This experiment was conducted in the Floriculture Unit of the Department of Horticulture, Faculty of Agriculture, Annamalai University. It was laid out in randomized block design and were replicated thrice. The sunflower cv. Ring of Fire was studied under three different NPK levels (4.5 : 2.25 : 2.25 g m⁻², 6.0 : 3.0 : 3.0 g m⁻² and 7.5 : 3.75 : 3.75 g m⁻² NPK) in combination with three levels of zinc (1.25 g m⁻², 2.5 g m⁻² and 3.75 g m⁻² ZnSO₄) and a control. Both NPK and zinc levels showed significant influence on all the foliage parameters, flowering parameters and leaf nutrient content of ornamental sunflower. The values of all the parameters evinced an increasing trend with higher doses of nutrients. The treatment T₁₀ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² recorded the highest values in terms of all the parameters viz., plant height (106.03 cm), plant spread (4283.56 cm²), number of leaves (27.65), leaf area (834.19 cm²), chlorophyll content (0.97 mg g⁻¹), days to fifty per cent flowering (54.06 days), flowering duration (41.34 days), number of flowers (14.37), flower diameter (14.96 cm), carotenoid content (0.37 mg g⁻¹), leaf nitrogen content (1.71%), phosphorus content (0.97%), potassium content (2.05%) and zinc content (0.0412%) which was on par with T₉ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻². Therefore, this study proves that the incorporation of NPK @ 7.5 : 3.75 : 3.75 g m⁻² along with ZnSO₄ @ 2.5 g m⁻² is the ideal fertilizer dose for ornamental sunflowers used as bedding plants.

Keywords: ornamental sunflower, nitrogen, phosphorus, potassium, zinc, bedding plant, growth, flowering

Introduction

Sunflower is gaining worldwide popularity as an ornamental crop in the last decade (Blacquiere *et al.*, 2002) [5]. Historically, sunflower was initially used as a garden plant, then as potted plants, and now as a cut flower. They are also employed as bedding plants in various landscape gardens. New cultivar development has created a vast range of plant forms and flower colours to meet the needs of the flower industry (Yanez *et al.*, 2005) [20]. The variety 'Ring of Fire' has a glowing golden yellow and reddish brown petals forming an indistinct ring around the dark center which is suitable to be grown as bedding plants. Bedding plants are grown either commercially or residentially to add colour to the gardens. These plants are grown in for their exquisite foliage, elegant flowers and unusual plant forms. The essential nutrients such as N, P and K are the components of inorganic fertilizers that are needed for growth and flowering of plants. The balanced NPK application increases the nutrient availability in the soil, thereby increasing the plant nutrient uptake. Zinc plays a major role in the activation of enzymes that are responsible for the protein synthesis. It is essential for the auxin formation and aids in stem elongation. The maximum growth of sunflowers could be achieved by applying balanced amount of fertilizers that supplies sufficient amount of nutrition to the plants (Handayati and Sihombing, 2019) [8]. Therefore timely fertilizer application at the critical growth stages could enhance the growth, flowering and quality of ornamental sunflowers. Fertilization standards have not been developed for sunflowers to be used as bedding plants. Hence the cultivar 'Ring of Fire' has been studied in the

view of standardizing the nutrient requirement to maximize the growth and flowering of ornamental sunflower grown as bedding plants.

Materials and methods

The experiment was conducted during March to May, 2019 in the Floriculture Unit of the Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalai nagar, Chidambaram, Tamil Nadu. The experimental site is located at 11°24' north latitude and 79°41' East longitude at an altitude of ±5.97 m above mean sea level (MSL) at about 6 km west of Bay of Bengal. The mean maximum temperature is 35.00° C, whereas the mean minimum temperature is 23.50° C. The mean relative humidity is 72 per cent. The soil type of the experimental field was clay loam with pH and EC of 7.45 and 0.40 dsm⁻¹ respectively. The variety of ornamental sunflower "Ring of Fire" was used for this study. The seeds were procured from Benary seeds, Germany. Randomized block design was followed with three replications maintaining 15 plants for each bed of size 1.6 x 1.6 m. Urea, Super phosphate and Muriate of potash fertilizers were used to supply N, P and K respectively.

The basal dose of application was half dose of nitrogen and full dose of phosphorus and potassium. The remaining half dose of nitrogen was top dressed at 30 DAS. Zinc sulphate was applied basally according to the respective treatments. Weeding was done periodically and integrated pest management was employed to control the pests and plant pathogens. The treatments comprised of three different doses of NPK along with three zinc levels and a control

treatment for comparison. The treatments are as follows : T₁ – Absolute control, T₂ - NPK @ 4.5 : 2.25 : 2.25 g m⁻² + ZnSO₄ @ 1.25 g m⁻², T₃ - NPK @ 4.5 : 2.25 : 2.25 g m⁻² + ZnSO₄ @ 2.5 g m⁻², T₄ - NPK @ 4.5 : 2.25 : 2.25 g m⁻² + ZnSO₄ @ 3.75 g m⁻², T₅ - NPK @ 6.0 : 3.0 : 3.0 g m⁻² + ZnSO₄ @ 1.25 g m⁻², T₆ - NPK @ 6.0 : 3.0 : 3.0 g m⁻² + ZnSO₄ @ 2.5 g m⁻², T₇ - NPK @ 6.0 : 3.0 : 3.0 g m⁻² + ZnSO₄ @ 3.75 g m⁻², T₈ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 1.25 g m⁻², T₉ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻², T₁₀ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻². The fertilizer doses were applied according to the treatments. The measurements for the objective data was taken from five plants, and for subjective data, one rating value representing all twenty five plants in the bed was given. The data were analyzed using the analysis of variance (ANOVA) methods.

Results and Discussion

All the studied foliage, flowering parameters and leaf nutrient status of ornamental sunflower increased with higher doses of nutrients. Increasing the concentrations of fertilizers had a positive influence on the sunflower plants. This might be ascribed to the higher nutrient availability to the plants that lead to the improvement in all the parameters of plant growth and development.

Foliage Parameters

Plant height

The data pertaining to the influence of NPK and zinc on plant height are presented in table 1. Significant differences were noticed in plant height treated with various levels of NPK and zinc. The highest plant height of 106.03 cm was observed in the plants treated with T₁₀ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was on par with the treatment T₉ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (105.27 cm). The lowest plant height (65.81cm) was obtained in plants under control (T₁). The internodes of the plants are lengthened by the meristematic activity of plants as well the protein synthesis leads to the increase in the plants height (Biswas and Poddar, 2015) [5]. Zinc also could have increased plant height by the auxin and protein synthesis in plants (Al-Doori *et al.*, 2011) [3]. Similar results were earlier reported by Jadia and Fulekar (2008) in sunflower.

Plant spread

The data on plant spread as affected by the influence of NPK and zinc levels are presented in Table 1. Among the various treatments, the widest plant spread of 4283.56 cm² was observed in the plants treated with T₁₀ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was on par with the treatment T₉ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (4209.66 cm²). This treatment was followed by the treatment T₈ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² NPK + Zn @ 0.25% recording a plant spread of 3856.30 cm².

The narrowest plant spread (1428.60 cm²) was obtained in plants under control (T₁). This might be due to the increased nutrient availability to the plants. Zinc also trigger enzymes such as carbonic dehydrogenase and tryptophan that are involved in various physiological processes (Joseph *et al.*, 2019). Similar findings were also reported by Ahmad *et al.* (2010) in rose.

Number of leaves

The data with respect to the effect of different NPK and zinc levels on the number of leaves are presented in Table 1. The results revealed that the number of leaves were significantly influenced by NPK and zinc at varying concentrations. Higher the concentrations, greater were the number of leaves. The highest number of leaves (27.65) was recorded in the plants treated with T₁₀ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was on par with the treatment T₉ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (27.51) whereas the lowest number of leaves (16.13) were obtained in the control plants (T₁). This might be due to enhanced plant heights because taller plants produce longer stems with increased foliage. Similar results were earlier documented by Fayaz *et al.* (2016) in gerbera.

Leaf area

All the nutrient doses at varying concentrations significantly increased the leaf area and the data are presented in Table 1. The highest leaf area of 834.19 cm² was obtained by plants treated with T₁₀ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was statistically on par with the treatment T₉ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (828.71 cm²) whereas the lowest leaf area (478.59 cm²) was obtained in the control plants (T₁). This is due to the fact that the increased nitrogen availability increased the foliage production. These results can be correlated with nitrogen content of leaves and photosynthesis. Dahiphale and Pawar (1993) also reported similar results in sunflower.

Chlorophyll content

According to the data on chlorophyll content listed in Table 1, it is evident that among the different levels of NPK and zinc used, the treatment T₁₀ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² recorded the highest chlorophyll content (0.97 mg g⁻¹) showing a rich green colour when compared to the other treatments. This treatment showed non significant differences with T₉ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (0.95 mg g⁻¹) whereas the lowest chlorophyll content (2.02 mg g⁻¹) was observed in the control (T₁). This is because nitrogen combined with phosphorous, potassium and zinc largely facilitates various plant metabolic functions leading to the production of chlorophyll and cytochrome. Similar observations were also reported by Zafar *et al.* (2014) in sunflower.

Flowering Parameters

Days to fifty per cent flowering

The number of days from sowing to fifty per cent flowering were significantly delayed by the influence of higher NPK and zinc concentrations (Table 2.). The most delayed flowering of 54.06 days was obtained in plants fertilized with T₁₀ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was on par with the treatment T₉ - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (54.02 days). Earliest flowering of 50.95 days was observed in the control plants (T₁). This could be due to the lustrous vegetative growth caused by higher NPK availability and uptake thereby prolonging the blooming days compared to control (T₁). These results are in line with those of Qadeer *et al.* (2019) in sunflower.

Flowering duration

The flowering duration of plants were significantly increased with the increase in the concentration of NPK and

zinc. The longest flowering duration of 41.34 days was observed in the treatment T_{10} - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was on par with the treatment T_9 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (41.02 days). However the shortest flowering duration (28.36 days) was seen in the control (T_1). Nitrogen might have extended the flowering duration as reported by Kumar *et al.* (2018) in marigold. Furthermore, phosphorus availability facilitates root growth and prolongs flowering duration. Zinc also activates metabolic processes causing the photosynthetic rate to increase and could have prolonged the flowering duration of sunflowers. Similar findings were also reported by Pal. *et al.* (2016) [15] in Gerbera.

Number of flowers

The data on the influence of NPK and zinc on the number of flowers are presented in Table 2. In the present study it was revealed that the highest number of flowers (14.37) were recorded in the treatment T_{10} - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was on par with the treatment T_9 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (14.28). However the lowest number of flowers (8.33) were obtained by the control (T_1). The increased phosphorus and potassium uptake could have increased the transport of metabolites thereby improving the vegetative growth and increasing the number of flowers. Due to improvement in growth attributes, zinc application might have also enhanced the number of flowers compared to control as documented by Kashif *et al.* (2014) [12] in Dahlia.

Flower diameter

The flower diameter was significantly increased by the effect of NPK and zinc at varying concentrations and are presented in Table 2. The largest flower diameter of 14.96 cm was recorded in the treatment T_{10} - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was on par with T_9 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (14.75 cm). The lowest flower diameter of 7.78 cm was recorded in the control (T_1) in comparison to all the other treatments. The increased vegetative growth caused by fertilizer doses might have affected the flower diameter significantly. These results are in harmony with those of Popoola *et al.* (2016) [16] in sunflower.

Carotenoid content

The carotenoid content increased with the increasing concentrations of NPK and zinc and the results are documented in Table 2. The highest carotenoid (0.37 mg g⁻¹) was recorded in the treatment T_{10} - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was statistically on par with T_9 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² (0.35 mg g⁻¹) whereas the lowest carotenoid content (0.12 mg g⁻¹) was recorded in the control (T_1) when compared to all the other treatments. Similar reports were also obtained by Adeoye *et al.* (2020) [11] in sunflower.

Leaf Nutrient Status

Nitrogen content

The nitrogen content in leaves under the influence of different concentrations of NPK and zinc are presented in

Table 3. The plants of the treatment T_{10} - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² recorded the highest nitrogen content (1.71%) in leaves which was on par with the treatment T_9 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² which had 1.69 per cent of nitrogen. The next best treatment was T_8 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 1.25 g m⁻² with 1.50 per cent of nitrogen in leaves. The lowest nitrogen content (0.83%) was observed in T_1 (control). The escalated leaf nitrogen content with higher NPK levels is ascribed to the greater availability of nitrogen and hence better uptake of nutrients by plants. Similar results were also documented by Singh (2000) in tuberose.

Phosphorus content

The data with respect to leaf phosphorus content as influenced by various fertilizer levels are depicted in Table 3. Significant variations were observed in the phosphorus content of leaves by various treatments. The highest P content (0.97%) was noticed in leaves of the plants grown in T_{10} - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was on par with the value (0.95%) of T_9 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + 2.5 g m⁻² ZnSO₄. This treatment was followed by T_8 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 1.25 g m⁻² with 0.86 per cent of phosphorus in the leaves whereas the lowest P content (0.41%) was observed with control. These observations were in corroboration with the findings of Nagaich *et al.* (2003) [14] in marigold.

Potassium content

The potassium content in leaves as influenced by various fertilizer concentrations varied significantly (Table 3). The highest potassium content (2.05%) was recorded in the leaves of the plants treated with T_{10} - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was on par with T_9 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² recording a potassium content of 2.02 per cent. This treatment was followed by T_8 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 1.25 g m⁻² with 1.91 per cent of potassium content in leaves. The control treated plants recorded the lowest potassium content (1.19%) in comparison to all the other treatments. Similar results were earlier reported by Lee *et al.* (2005) [13] in chrysanthemum.

Zinc content

The data pertaining to the influence of NPK and zinc combinations at varying levels on the zinc content in leaves are presented in Table 3. The zinc content in the leaves of ornamental sunflower increased with increasing fertilizer doses of NPK and zinc. The highest zinc content (0.0412%) was registered in the leaves of the plants treated with T_{10} - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 3.75 g m⁻² which was statistically on par with the treatment T_9 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 2.5 g m⁻² which had 0.0409 per cent of zinc in the leaves. This treatment was followed by T_8 - NPK @ 7.5 : 3.75 : 3.75 g m⁻² + ZnSO₄ @ 1.25 g m⁻² with 0.0398 per cent zinc in the leaves. The lowest zinc content (0.0305%) was recorded with the treatment T_1 i.e., control. Similar trend were reported by Shanmugasundaram and Savithri (2006) [18] who recorded maximum zinc concentration in sunflowers with higher zinc levels.

Table 1: Effect of NPK and zinc on plant height, plant spread, number of leaves, leaf area and chlorophyll content of ornamental sunflower cv. Ring of Fire

Treatments	Plant height (cm)	Plant spread (cm ²)	No. of leaves	Leaf area (cm ²)	Chloro-phyll content (mg g ⁻¹)
T ₁ – Absolute control	65.81	1284.03	16.13	478.59	0.68
T ₂ – NPK @ 4.5 : 2.25 : 2.25 g m ⁻² + ZnSO ₄ @ 1.25 g m ⁻²	85.55	2106.53	20.98	612.61	0.74
T ₃ – NPK @ 4.5 : 2.25 : 2.25 g m ⁻² + ZnSO ₄ @ 2.5 g m ⁻²	87.03	2436.71	21.03	639.64	0.77
T ₄ – NPK @ 4.5 : 2.25 : 2.25 g m ⁻² + ZnSO ₄ @ 3.75 g m ⁻²	87.22	2508.86	21.12	646.33	0.78
T ₅ – NPK @ 6.0 : 3.0 : 3.0 g m ⁻² + ZnSO ₄ @ 1.25 g m ⁻²	91.35	2788.25	21.38	661.93	0.82
T ₆ – NPK @ 6.0 : 3.0 : 3.0 g m ⁻² + ZnSO ₄ @ 2.5 g m ⁻²	94.87	3241.45	22.97	726.67	0.86
T ₇ – NPK @ 6.0 : 3.0 : 3.0 g m ⁻² + ZnSO ₄ @ 3.75 g m ⁻²	95.04	3322.59	23.01	735.22	0.88
T ₈ – NPK @ 7.5 : 3.75 : 3.75 g m ⁻² + ZnSO ₄ @ 1.25 g m ⁻²	100.11	3656.30	25.06	785.84	0.91
T ₉ – NPK @ 7.5 : 3.75 : 3.75 g m ⁻² + ZnSO ₄ @ 2.5 g m ⁻²	105.27	4166.72	27.51	828.71	0.95
T ₁₀ – NPK @ 7.5 : 3.75 : 3.75 g m ⁻² + ZnSO ₄ @ 3.75 g m ⁻²	106.03	4243.56	27.65	834.19	0.97
S.Ed.	0.63	42.05	0.09	5.51	0.01
C.D. (0.05)	1.26	84.11	0.19	11.03	0.03

Table 2: Effect of NPK and zinc on days to fifty per cent flowering, flowering duration, number of flowers, flower diameter and carotenoid content of ornamental sunflower cv. Ring of Fire

Treatments	Days to fifty percent flowering (days)	Flowering duration (days)	No. of flowers	Flower diameter (cm)	Carotenoid content (mg g ⁻¹)
T ₁ – Absolute control	50.95	28.36	8.33	7.78	0.11
T ₂ – NPK @ 4.5 : 2.25 : 2.25 g m ⁻² + ZnSO ₄ @ 1.25 g m ⁻²	52.02	31.22	11.35	10.54	0.15
T ₃ – NPK @ 4.5 : 2.25 : 2.25 g m ⁻² + ZnSO ₄ @ 2.5 g m ⁻²	52.09	33.28	12.83	11.25	0.18
T ₄ – NPK @ 4.5 : 2.25 : 2.25 g m ⁻² + ZnSO ₄ @ 3.75 g m ⁻²	52.12	33.69	12.96	11.35	0.21
T ₅ – NPK @ 6.0 : 3.0 : 3.0 g m ⁻² + ZnSO ₄ @ 1.25 g m ⁻²	52.81	35.53	12.98	12.11	0.23
T ₆ – NPK @ 6.0 : 3.0 : 3.0 g m ⁻² + ZnSO ₄ @ 2.5 g m ⁻²	53.01	37.85	13.32	12.87	0.26
T ₇ – NPK @ 6.0 : 3.0 : 3.0 g m ⁻² + ZnSO ₄ @ 3.75 g m ⁻²	53.15	38.01	13.36	12.94	0.28
T ₈ – NPK @ 7.5 : 3.75 : 3.75 g m ⁻² + ZnSO ₄ @ 1.25 g m ⁻²	53.84	39.65	13.82	14.05	0.31
T ₉ – NPK @ 7.5 : 3.75 : 3.75 g m ⁻² + ZnSO ₄ @ 2.5 g m ⁻²	54.02	41.02	14.28	14.75	0.35
T ₁₀ – NPK @ 7.5 : 3.75 : 3.75 g m ⁻² + ZnSO ₄ @ 3.75 g m ⁻²	54.06	41.34	14.37	14.96	0.37
S.Ed.	0.06	0.54	0.05	0.18	0.01
C.D. (0.05)	0.13	1.08	0.11	0.37	0.02

Table 3: Effect of NPK and zinc on leaf nutrient status of ornamental sunflower cv. Ring of Fire

Treatments	Nitrogen (per cent)	Phosphorus (percent)	Potassium (percent)	Zinc (percent)
T ₁ – Absolute control	0.83	0.41	1.19	0.0305
T ₂ – NPK @ 4.5 : 2.25 : 2.25 g m ⁻² + ZnSO ₄ @ 1.25 g m ⁻²	1.01	0.53	1.32	0.0319
T ₃ – NPK @ 4.5 : 2.25 : 2.25 g m ⁻² + ZnSO ₄ @ 2.5 g m ⁻²	1.13	0.61	1.41	0.0324
T ₄ – NPK @ 4.5 : 2.25 : 2.25 g m ⁻² + ZnSO ₄ @ 3.75 g m ⁻²	1.19	0.64	1.43	0.0328
T ₅ – NPK @ 6.0 : 3.0 : 3.0 g m ⁻² + ZnSO ₄ @ 1.25 g m ⁻²	1.28	0.70	1.56	0.0342
T ₆ – NPK @ 6.0 : 3.0 : 3.0 g m ⁻² + ZnSO ₄ @ 2.5 g m ⁻²	1.40	0.79	1.75	0.0361
T ₇ – NPK @ 6.0 : 3.0 : 3.0 g m ⁻² + ZnSO ₄ @ 3.75 g m ⁻²	1.42	0.80	1.79	0.0365
T ₈ – NPK @ 7.5 : 3.75 : 3.75 g m ⁻² + ZnSO ₄ @ 1.25 g m ⁻²	1.50	0.86	1.91	0.0398
T ₉ – NPK @ 7.5 : 3.75 : 3.75 g m ⁻² + ZnSO ₄ @ 2.5 g m ⁻²	1.69	0.95	2.02	0.0409
T ₁₀ – NPK @ 7.5 : 3.75 : 3.75 g m ⁻² + ZnSO ₄ @ 3.75 g m ⁻²	1.71	0.97	2.05	0.0412
S.Ed.	0.02	0.01	0.02	0.0002
C.D. (0.05)	0.04	0.02	0.04	0.0004

Conclusion

The present study reveals that a good quality bedding plant can be produced when ornamental sunflowers are fertilized with NPK @ 7.5: 3.75: 3.75 g m⁻² in combination with ZnSO₄ @ 2.5 g m⁻². The use of such balanced fertilizers can increase the efficiency of plants and also the cost is moderate. Therefore this treatment combination when used for ornamental sunflowers grown as bedding plants can benefit a variety of landscapes.

References

1. Adeoye O, Pitan O, Akinkunmi O, Akinyemi O. Synergistic interactions between honeybee *Apis mellifera* L. and flower colour of sunflower in response to NPK fertilizer application. Ethiopian Journal of

Environmental Studies and Management,2015:13(4):495-508.
 2. Ahmad I, Khan MA, Qasim M, Ahmad R, Randhawa MA. Growth, yield and quality of *Rosa hybrida* L. as influenced by various micronutrients. Pakistan Journal of Agricultural Sciences,2014:47(1):5-12.
 3. Al-Doori SA. Effect of different levels and timing of zinc foliar application on growth, yield and quality of sunflower genotypes (*Helianthus annuus* L.). College of Basic Education Researchers Journal,2014:13(1):907-922.
 4. Biswas B, Poddar R. Yield and nutrients uptake of sunflower (*Helianthus annuus* L.) as influenced by different level of nitrogen and sulphur. The Bioscan.,2015:10(1):439-444.

5. Blacquiére T, Straver N, Van Den Berg, D. Possibilities for using photoperiodism to program flowering of sunflowers (*Helianthus annuus*) in the greenhouse and in the open. *Acta Horticulture*,2009:580(1):101-109.
6. Dahiphale VV, Pawar KR. Effects of irrigation schedules on dry matter production and biometric growth parameters of rabi sunflower. *Jornal of Maharashtra Agricultural University*,2019:18(3):358-360.
7. Fayaz K, Singh D, Singh VK, Bashir D, and Kuller LR. Effect of NPK on plant growth, flower quality and yield of gerbera (*Gerbera jamesonii*). *Research in Environment and Life Sciences*,2016:9(1):1361-1363.
8. Handayati W, Sihombing D. Study of NPK fertilizer effect on sunflower growth and yield. In *AIP Conference Proceedings.*, 2120, 030031-1-030031-4
9. Jadia CD, Fulekar MH. Phytoremediation: The application of vermicompost to remove zinc, cadmium, copper, nickel and lead by sunflower plant. *Environmental Engineering and Management Journal*,2008:7(5):547-558.
10. Joseph A, Prasad VM, Bahadur V, Samir ET, Deepanshu. Effect of micronutrients on growth, flower quality and yield of China aster (*Callistephus chinensis* L) under Allahabad agro climatic condition. *The Pharma Innovation Journal*,2009:8(7):609-613.
11. Kumar R, Kumar A, Kumar A. Effect of nutrients on growth, flowering and yield of african marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gaiinda. *International Journal of Current Microbiology and Applied Sciences*,2008:7(6):205-209.
12. Kashif M, Rizwan K, Khan MA, Younis A. Efficacy of macro and micronutrients as foliar application on growth and yield of *Dahlia hybrida* L. *International Journal of Chemical and Biochemical Sciences*,2014:5(1):6-10.
13. Lee KD, Supaniani MSY, Smith DL, Fertilizer effect on the yield and terpene components from the flower heads of *Chrysanthemum boreale* M. *Agronomie*,2005:25(1):205-211.
14. Nagaich KN, Trivedi SK, Lekhi R. Effect of nitrogen and phosphorus on growth, flowering, yield and quality of marigold. *Scientific Horticulture*,2009:8(1):203-209.
15. Pal S, Barad AV, Singh AK, Khadda BS, Kumar D. Effect of foliar application of Fe and Zn on growth, flowering and yield of gerbera (*Gerbera jamesonii*) under protected condition. *Indian Journal of Agricultural Sciences*,2016:86(3):394-398.
16. Popoola O, Adesanya K, Olawale O, Ayanrinde A. Factorial analysis on the effect of npk fertilizer, micronutrients and n-placement on the growth and yield of sunflower. *International Journal of Engineering Science Research*,2016:4(1):22-37.
17. Qadeer A, Tahir MM, Abbasi MK, Ali A, Rasheed A. Morphological and phenological responses of sunflower to nitrogen fertilization and plant growth promoting rhizobacteria under rainfed conditions in Pakistan: Morpho-phenological responses of sunflower to plant growth promoting rhizobacteria and nitrogen. *Proceedings of the Pakistan Academy of Sciences: B. Life and Environmental Sciences*,2019:56(1):41-48.
18. Shanmugasundaram R, Savithri P. Effect of levels and frequency of zinc sulphate application on its content and uptake by maize and sunflower in their sequential cropping system. *Agricultural Science Digest*,2006:26(1):31-34.
19. Singh KP. Response of graded levels of nitrogen in tuberose (*Polianthes tuberosa* L.) cv. Single. *Advances in Plant Sciences*,2005:13(1):283-285.
20. Yanez P, Ohno H, Ohkawa K. Photoperiodic response and vase life of ornamental sunflower cultivars. *HortTechnology*,2005:15(2):386-390.
21. Zafar S, Nasri M, Moghadam HRT, Zahedi. Effect of zinc and sulfur foliar applications on physiological characteristics of sunflower (*Helianthus annuus* L.) under water deficit stress. *International Journal of Biosciences*,2014:5(12):87-96.