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OPTIMAL PRODUCTION PROTOCOLS FOR CUT *HELIANTHUS ANNUUS* L.

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Abstract

Sunflower (*Helianthus annuus* L.) is extensively cultivated as a specialty cut flower in many parts of the world and is increasingly popular in Asian cut flower markets. Being a relatively new cut flower crop in the region, its production practices ought to be optimized to get the best possible cut stem production. Five production experiments were conducted: 1. planting time, 2. planting method, 3. planting density, 4. macro and micro-nutrients along with biostimulants and 5. varietal evaluation. Tallest plants with highest fresh and dry weight of the stem were noted when planted on 19 May, followed by 3 May. Shortest production time was also recorded for planting on 19 May followed by 3 May. Tallest plants with greatest stem fresh weight, stem dry weight and smallest flower diameter were recorded when plants were grown on ridges, followed by raised beds, while least production time was observed for plants grown on flat beds. Plants transplanted at 15×15 cm were the tallest plants and had the greatest flower quality. Greatest flower diameter and shortest production time were recorded for plants grown on 30×30 cm spacing. The intermediate spacings of 15×22.5 cm, 22.5×22.5 cm, 22.5×30 cm produced intermediate results for most variables. For nutritional study, application of NPK + isabion (0.4%) produced tallest plants with greatest flower diameter and shortest production, followed by NPK + humic acid (0.4%), which also had greatest stem diameter along with NPK alone. Among varieties, 'Tall Red Sun' produced the tallest plants followed by 'Vincent Choice', while 'Vincent Choice' produced stems with the shortest production time and had best quality cut stems. In summary, 'Vincent Choice sown on 19 May produced best quality stems, while planting on ridges or raised beds with 15×15 cm plant spacing and fertilization with NPK along with isabion proved best for optimal stem length and flower diameter with least production time and may be used for high quality cut sunflower production.

Key words: Specialty cuts; Sowing time; Plant spacing; Nutritional levels; Cultivars; Vincent choice

Introduction

Floriculture is a fast growing, highly competitive global enterprise. The demand for floricultural products and production of flower and foliage crops is increasing in the international floriculture trade. Cut flower production has shifted to areas where the conditions are favorable and production expenses are low as compared to conventional production centers (Zhao *et al*., 2008).

Cut flowers contribute around 45% share of the total global trade in floricultural commodities. The floriculture industry is enhancing farm income and reducing poverty in several developing countries. According to ITC report, there is around 9% annual increase in global floriculture trade along with 17% increase in trade share of growing countries (Augiar *et al.*, 2022).

As with most industries, floriculture businesses are actively searching for new crops and cultivars along with innovative trends and niches to boost product sales. Sunflower (*Helianthus annuus* L.), belongs to Asteraceae family, are grown for their colorful blooms, which can range from small to very big, and in color from the traditional yellow to shades of orange, red, and even bi-colored varieties. Sunflowers are now widely grown as a specialty cut flower and are tolerant of a variety of climates and soil types. Sunflowers typically reach maturity within 50-70 days, and their blooms can last for a week or so, making them a popular choice for both personal and commercial use. Optimal conditions for growing sunflowers are a soil pH between 5.7 and 7.0, temperatures ranging from 18 to 24°C, adequate potassium for strong stems, and full sunlight (Schoellhorn *et al*., 2003).

Sunflower production as cut flower has recently been adopted in Pakistan within the last few years, but the production protocols for this crop are yet to be optimized. We can attain the ideal flower quality and yield by manipulating the ideal planting time, planting method, planting densities and optimum macro and micronutrients applications along with biostimulants use for enhancing growth and stress alleviation. Moreover, evaluation of various cultivars in local agro-climatic conditions are required for recommendation of best suited varieties.

Planting time for cut flowers is a critical factor that significantly affects the growth, development, and quality of the cut stems. Planting at the right time can help produce high-quality cut stems and allow them to be available for special events and festivities. The ideal planting density varies depending on the specific crop being grown, but generally, a higher planting density can result in more flowers per unit area and smaller flower heads, which can be important for maximizing profits in commercial cut sunflower production.

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Sunflower requires a balanced supply of nutrients to grow and develop properly. The pH range of 7.8 to 8.3 found in most soils of Pakistan, that is inappropriate for the adequate absorption of nutrients, such as iron, manganese. Fertilizer application usually affects growth and yield as compared to unfertilized vegetation. An optimal concentration of macro and micronutrients in plant nutrition is very important for higher yields of best quality cut stems (Hussain *et al*., 2011). Crop growth is enhanced by biochemicals and natural plant extracts and getting popularity for their environment friendly nature (Godlewska *et al*., 2019). A broad range of bioactive substances found in plant extracts are known as agricultural biostimulants, which are being used alternative to chemical fertilizers in crop production (Rouphael & Colla, 2020). Both macro and micronutrients are required for the several biochemical activities that take place inside the plant and are essential for the growth and development of the plant. Different biostimulants counteract the impacts of biotic and abiotic stresses, increase quality and enhance crop yield by influencing various plant physiological processes and root development (Toscano *et al.*, 2018).

This study was aimed to provide growers and florists with evidence-based protocols to optimize the production management of cut sunflower for improved quality, extended vase life, increased economic returns and sustainability. Moreover, the implementation of optimized protocols can result in improved marketability and increased economic returns of cut sunflower. This study would also contribute to sustainability efforts by minimizing resource consumption and promoting environment friendly practices in cut sunflower production.

There is very limited literature available about the production of cut sunflower in local agro-climatic conditions. Therefore, primary goal of this study was to enhance the methods for production of cut sunflower in the specific agro-climatic conditions of Punjab, Pakistan. to produce high quality cut stems and to maintain their quality after harvest for longer periods. It was hypothesized that optimal production protocols for cut sunflower will help to produce best quality cut stems with longer vase life that will enhance quality and economic viability.

Material and Methods

Plant material and experimental design: This research was carried out at the Floriculture Research Area, Institute of Horticultural Sciences at the University of Agriculture, Faisalabad, Pakistan. The study took place in the year 2022-23 and its geographical coordinates are latitude 31°30 N, longitude 73°10E, and altitude 213 m. In this study, five production experiments were conducted to determine the effect of planting time, planting methods, planting densities, macro and micronutrients along with biostimulants and varieties on cut sunflower production. In Expt. 1, 'Vincent Choice' sunflower seeds were sown five times at intervals of either 15 or 16 days: 19 Mar, 3 Apr, 19 Apr, 3 May and 19 May. The seedlings of cut sunflower were raised in 72-cell plastic plug trays filled with a substrate containing silt, UAF-Gro (a patented indigenous soilless substrate made from local materials), and coco coir in equal proportions (1:1:1; v/v/v). from 19 March 2022 to 19 May 2022. The seedlings were grown in a greenhouse that was kept at 25±3°C and 50±10% relative humidity. The seedlings were transplanted onto raised beds in open field after the soil was thoroughly prepared, leveled, and laid out. The transplanting was done at 2-4 true leaf stage according to a randomized complete block design (RCBD) with four replications and each replication had twenty-four plants.

For Expt. 2, 'Vincent Choice' sunflower seedlings were transplanted at 15×15 cm spacing using different planting methods on 25 March 2022, at 2-4 true leaf stage. Cultural practices were same as described in Expt. I. One-week-old seedlings were transplanted at 15×15 cm spacing on flat beds, ridges and raised beds (containing single row).

For Expt. 3, 'Vincent Choice' sunflower seedlings were transplanted at raised beds on different planting densities: 15 × 15, 15 × 22.5, 22.5 × 22.5, 22.5 × 30 and 30 × 30 cm apart, on 15 June.

In Expt. 4, 'Vincent Choice' sunflower seedlings were transplanted at 15 × 15 cm spacing on raised beds on 15 September. First dose of N (90 kg ha^{-1}) and NPK (90:45:45 kg ha^{-1}) were applied at transplanting, while second dose was applied 15 days after transplantation. Three sprays of each biostimulants: 0.4% isabion, 0.4% humic acid and micronutrients (B, Zn, Fe) (1%, 1% & 1%) were applied until runoff at ten days interval after transplanting in addition to NPK (90:45:45 kg ha^{-1}).

In Expt. 5, seedlings of 'Vincent Choice', 'Tall Red Sun' and 'Teddy Bear' were transplanted on ridges at 15×15 cm spacing on 29 May. Prior to transplantation, herbicide applied before emergence (Dual Gold, s-metolachlor, Syngenta, Pakistan) at 5 mL L^{-1} and NPK fertilizer (15:15:15) was added at 250 kg ha^{-1}. Throughout the study, all other cultural techniques, which includes fertigation, irrigation, controlling weeds, integrated pest management (IPM), etc., were same for every treatment.

Data collection

At harvest data were collected for various parameters including production time (counted in days between the transplant and harvest), plant height (measured in centimeters from the ground level to the top of plant), stem length (cm), leaf total chlorophyll contents (SPAD), flower diameter (cm), stem fresh weight (g) using an electronic weighing balance (Model: HK-DC-320AS), stem dry weight (g) obtained after drying samples in an oven at 75°C for 72 hours, stem diameter (mm), number of leaves counted manually per stem and leaf area (cm^2) of three leaves per plant. The leaf area determined using the method of measurement (leaf area = length × maximum breadth × 0.68) as stated by Carleton and Foote (1965). The quality of the flowers was evaluated by three assessors using a scale ranging from 1 to 9, where 9 being the highest quality, 5 represents average quality, and 1 represents poor quality of stems (Cooper & Spokas, 1991). The fresh and dry weight of the stems was measured, including all leaves and flower heads. Sunflower stems were harvested at commercial maturity when the flowers were partially opened and before the petals were parallel to the flower head. For the evaluation of vase life, the stems were collected in the early morning before 08:00 AM, as previously stated above. After harvesting, stems were transferred within an hour to the postharvest laboratory by placing them in buckets filled with water. Upon arrival, the stems were trimmed to a length of 60 cm from the base and put into jars filled with distilled water to assess their longevity in a vase. The stems were placed in a postharvest laboratory with a temperature of 22 ± 2°C, a relative humidity of 60 ± 10%, and a photosynthetic photon flux density of 8-12 μ mol $m^{-2} s^{-1}$. The light was given by white fluorescent tubes operating on a 12-hour daily photoperiod. There were five replicate jars for each treatment, each containing two stems.

Statistical analysis

Data were analyzed statistically using analysis of variance (ANOVA) technique according to Fisher's technique of analysis (Statistix 8.1) and treatment means were compared according to Least Significant Difference test at 5% level of probability (Steel *et al*., 1997).

Results

Planting times: Sunflower plants sown on 19 May had the shortest time (40 d) to harvest, while those sown on 19 Mar. took 49 d to produce harvestable stems (Table 1). The least time to harvestable stems not only reduced production cost, but also lowered biotic and abiotic stresses such as drought and disease incidence (personal observation). Tallest plants (122 cm) were produced when planted on 19 May with highest stem fresh weight (681 g), leaf area (416 cm^2), dry weight (120.4 g), leaf total chlorophyll contents (SPAD) (41.9 SPAD) and longest vase life (9 d). Flower quality was not affected by planting times (data not presented). Cut stem vase life was also similar for the first four sowings in the season, which averaged 7 days. Greatest stem diameter (20.1 mm) was recorded for the 3 May planting, followed by 19 May (18.6 mm).

Planting methods: Sunflower plants transplanted on ridges and raised beds had longest production time (46 d each) (Table 2). Sunflower transplanted on ridges showed the tallest plants (105 cm) with highest stem fresh weight (495 g) and dry weight (56.3 g) and smallest flower diameters (14.2 cm). Flower quality was lower for raised beds (8.4) than the other planting methods (9.0 each). Greatest stem diameter (17.4 mm) was recorded in plants sown on raised beds, followed by flat beds (16.1 mm). Vase life, leaf total chlorophyll contents and leaf area was similar for all planting methods (data not presented).

Planting densities: Plants transplanted at 15×15 cm spacing showed tallest plants (120 cm) with highest stem fresh weight (739 g), dry weight (111.8 g) and flower quality (9) (Table 3). Greatest flower diameter (21.9 cm), leaf area (400 cm^2), leaf total chlorophyll content (SPAD) (62.8 SPAD) and stem diameter (19.4 mm) were recorded in 30×30 cm. Sunflower plants transplanted on 30×30 cm spacing had least production time (40 d), which was similar for other closer planting densities.

Macro and micronutrients along with biostimulants: Least production time (40 d) was recorded when plants were supplied with NPK + isabion (0.4%) along with highest plant height (83.1 cm), flower diameter (16.5 cm), vase life (8 d) and stem fresh weight (369.4 g) (Table 4). Greatest stem diameter (15.2 mm and 15.1 mm) was recorded in NPK alone and NPK + humic acid, respectively (Fig. 1). Leaf total chlorophyll contents and flower quality was similar in all treatments (data not presented). Regarding different nutrient applications, NPK + isabion exhibited highest leaf N contents (4.5%) followed by NPK + humic acid (4.4%) (Fig. 2). Lowest N contents were recorded in plants with no nutrient application (control) (3.0%). NPK + micronutrients, NPK + isabion and NPK + humic acid exhibited greatest leaf P contents (0.6% each) and were statistically similar. Lowest P contents were obtained in plants with no nutrient application (control) (0.3%). NPK + micronutrients exhibited highest K contents (3.4%) followed by NPK + isabion and NPK + humic acid (3.2% and 3.2%).

Cultivars: Among tested cultivars, shortest production time (43 d) was recorded in 'Vincent Choice' with greatest stem diameter (21.2 mm) (Table 5). Highest flower quality (9) was also recorded in 'Vincent Choice'. 'Tall Red Sun' showed tallest plants (138 cm), highest stem fresh weight (768 g) and dry weight (116 g), while shortest plants (34 cm) with the lowest leaf area (209 cm^2) were recorded in 'Teddy Bear'. Highest flower diameter (17.1 cm), best flower quality (9) and longest vase life (7 d) were also recorded in 'Vincent Choice'. Leaf total chlorophyll contents were similar in all three cultivars (data not presented).

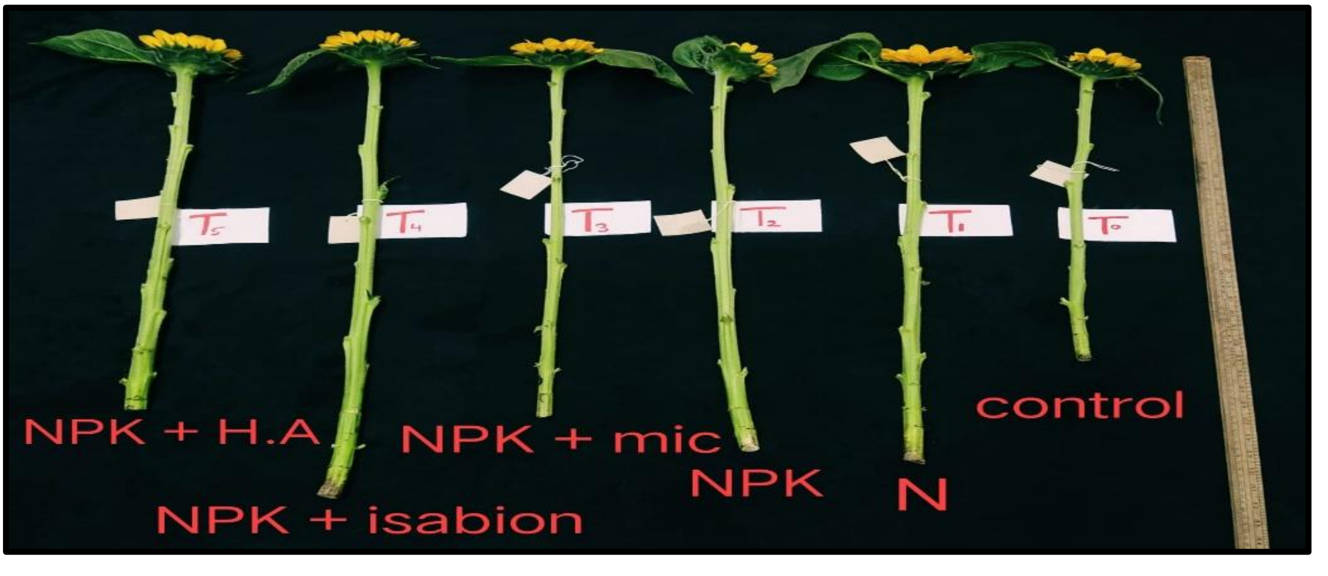

Fig. 1. Treatment comparison of different nutritional levels of sunflower (*Helianthus annuus* L.).

Table 1. Effect of different planting times on production time (days), plant height (cm), flower diameter (cm), stem fresh weight (g), stem dry weight (g), stem diameter (mm), leaf area (cm^2) and leaf total chlorophyll contents (SPAD) of sunflower (*Helianthus annuus* L.) Data represents means of 40 stems.

Treatments (Planting times)	Production time (days)	Plant height (cm)	Flower diameter (cm)	Stem fresh weight (g)	Stem dry weight (g)	Stem diameter (mm)	Leaf area (cm^2)	Leaf total chlorophyll contents (SPAD)
March 19	48.5 a[z]	88 c	14.5 ab	326 b	42.4 c	17.3 c	348 b	32.2 c
April 03	46.5 b	66 b	15.9 a	340 b	41.6 c	17.5 bc	203 c	36.0 b
April 19	44.9 bc	110 a	13.8 b	632 a	96.8 b	19.0 ab	397 ab	37.4 b
May 03	43.8 c	117 a	15.0 ab	630 a	88.4 b	20.1 a	395 ab	36.9 b
May 19	39.9 d	122 a	14.8 ab	681 c	120.4 a	18.6 ab	416 a	41.9 a
Significance[y]	<0.0001	<0.0001	0.02125	<0.0001	<0.0001	0.0119	<0.0001	0.0007

[z] Means separation within columns by Fisher's LSD at $p<0.05$

[y] *P* values were obtained using general linear models (GLM) procedures of statistics (version 8.1, analytical software) for significant effects of different planting times on sunflower (*Helianthus annuus* L.)

Table 2. Effect of different planting methods on production time (days), plant height (cm), stem diameter (mm), flower diameter (cm), stem fresh weight (g), stem dry weight (g) and flower quality of sunflower (*Helianthus annuus* L.) data represents means of 40 stems.

Treatments (planting methods)	Production time (days)	Plant height (cm)	Stem diameter (mm)	Flower diameter (cm)	Stem fresh weight (g)	Stem dry weight (g)	Flower quality (1-9)
Raised beds	46.0 a[z]	96 b	17.4 a	16.2 a	490 a	50.1 a	8.4 b
Flat beds	44.3 b	86 c	16.1 b	15.6 a	375 b	37.9 b	9.0 a
Ridges	46.2 a	105 a	15.4 b	14.2 b	495 a	56.3 a	9.0 a
Significance[y]	0.0343	0.0048	0.0055	0.0010	0.010	0.0086	0.017

[z] Means separation within columns by Fisher's LSD at $p<0.05$

[y] *P* values were obtained using general linear models (GLM) procedures of statistics (version 8.1, analytical software) for significant effects of different planting methods on sunflower (*Helianthus annuus* L.)

Table 3. Effect of different planting densities on production time (days), plant height (cm), Flower diameter (cm), stem fresh weight (g), stem dry weight (g), stem diameter (mm), leaf area (cm^2), leaf total chlorophyll contents (SPAD) and flower quality (1-9) of sunflower (*Helianthus annuus* L.). Data represents means of 40 stems.

Treatments (Planting densities)	Production time (days)	Plant height (cm)	Flower diameter (cm)	Stem fresh weight (g)	Stem dry weight (g)	Stem diameter (mm)	Leaf area (cm^2)	Leaf total chlorophyl contents (SPAD)	Flower quality (1-9)
15×15 cm	45.9 a[z]	120 a	15.6 d	739 a	111.8 a	14.1 d	394	31.8 c	9.0 a
15×22.5 cm	45.9 a	118 a	17.8 c	629 b	88.4 b	16.3 c	397	38.1 bc	8.0 b
22.5×22.5 cm	43.0 b	94 c	16.8 cd	611 b	82.5 b	17.5 bc	394	41.6 b	6.2 c
22.5×30 cm	43.1 b	100 b	19.3 b	617 b	77.7 b	18.6 ab	399	37.0 bc	6.5 c
30×30 cm	40.3 c	89 d	21.9 a	735 a	118.5 a	19.4 a	400	62.8 a	6.0 c
Significanc[y]	<0.0001	<0.0001	<0.0001	0.0005	0.0007	<0.0001	NS	<0.0001	<0.0001

[z] Means separation within columns by Fisher's LSD at $p<0.05$.

[y] *P* values were obtained using general linear models (GLM) procedures of statistix (version 8.1, analytical software) for significant effects of different planting densities on sunflower (*Helianthus annuus* L.)

[NS] Non-significant at $p>0.05$

Table 4. Effect of different nutritional regimes on production time (days), plant height (cm), Flower diameter (cm), stem fresh weight (g), stem dry weight (g), stem diameter (mm), leaf area (cm^2), and vase life of sunflower (*Helianthus annuus* L.). Data represents means of 40 stems.

Treatments (Nutritional levels)	Production time (days)	Plant height (cm)	Flower diameter (cm)	Stem fresh weight (g)	Stem dry weight (g)	Stem diameter (mm)	Leaf area (cm^2)	Vase life (days)
Control (0 kg ha^{-1})	49.1 a[z]	53 f	5.9 f	184 f	23.1	10.4 c	205 b	5.2 d
N (90 kg ha^{-1})	46.5 b	57 e	10.1 e	219 e	36.2	12.6 b	393 a	7.0 c
NPK (90:45:45 kg ha^{-1})	45.0 bc	67 c	12.1 d	268 c	56.3	15.2 a	400 a	7.0 c
NPK (90:45:45 kg ha^{-1}) + micronutrient (1%)	41.3 de	64 d	13.1 c	243 d	65.5	12.9 b	392 a	7.6 b
NPK (90:45:45 kg ha^{-1}) + isabion (0.4%)	39.8 e	83 b	16.5 a	369 a	69.6	14.9 b	394 a	8.0 a
NPK (90:45:45 kg ha^{-1}) + humic acid (0.4%)	43.4 cd	71 a	14.6 b	350 b	48.4	15.1 a	390 a	7.6 b
Significance[y]	<0.0001	<0.0001	<0.0001	<0.0001	NS	<0.0001	<0.0001	<0.0001

[z] Means separation within columns by Fisher's LSD at $p<0.05$
[y] *P* values were obtained using general linear models (GLM) procedures of statistix (version 8.1, analytical software) for significant effects of different nutritional regimes on sunflower (*Helianthus annuus* L.)
[NS] Non-significant at $p>0.05$

Table 5. Effect of different cultivars on production time (days), plant height (cm), Flower diameter (cm), stem fresh weight (g), stem dry weight (g), stem diameter (mm), leaf area (cm^2), leaf total chlorophyll contents (SPAD), flower quality (1-9) and vase life of sunflower (*Helianthus annuus* L.). Data represents means of 40 stems.

Treatments (Varietal evaluation)	Production time (days)	Plant height (cm)	Flower diameter (cm)	Stem fresh weight (g)	Stem dry weight (g)	Stem diameter (mm)	Leaf area (cm^2)	Flower quality (1-9)	Vase life (days)
Vincent's Choice	43.0 c[z]	98 b	17.1 b	615 b	85.5 b	16.87 b	394 a	9.0 a	7.0 a
Teddy Bear	61.2 a	34 c	5.9 c	181 c	23.2 c	8.53 c	209 b	4.1 a	5.2 b
Tall Red Sun	51.5 b	138 a	18.9 a	768 a	116.3 a	21.21 a	397 a	6.8 c	5.2 b
Significance[y]	<0.0001	0.0001	<0.0001	<0.0001	0.0007	<0.0001	<0.0001	0.0014	0.0001

[z] Means separation within columns by Fisher's LSD $p<0.05$
[y] *P* values were obtained using general linear models (GLM) procedures of statistix (version 8.1, analytical software) for significant effects of different cultivars on sunflower (*Helianthus annuus* L).
[NS] Non-significant at $p>0.05$

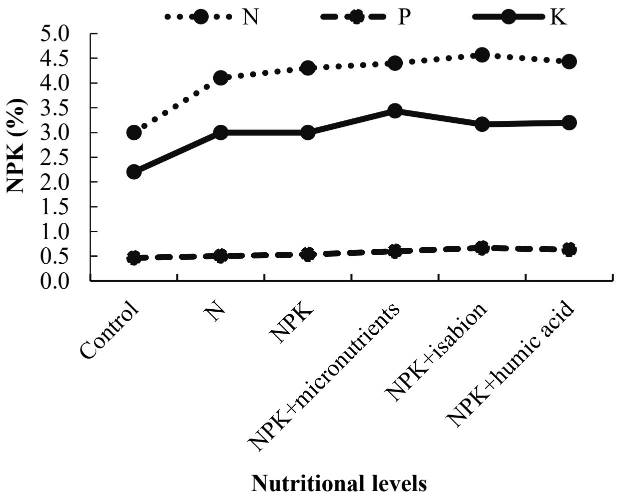

Fig. 2. Effect of different nutritional levels on leaf N, P and K contents of sunflower (*Helianthus annuus* L.). All lines represent means of 40 plants ± S.E.

Discussion

Planting sunflowers late in the season during summer reduced production time from 49 to 40 days. During plant growth, temperature regime affects stem elongation and flower development (Kamenetsky & Dole, 2012). The shorter production time not only reduced cost of production, but also lowered biotic and abiotic stresses like drought and disease incidence. Sunflowers are typically grown during the warm times of the year due to their heat tolerance and the higher temperatures during the month of May accelerated their growth and development. Favorable temperatures at sowing time may lead to rapid germination followed by vigorous seedling growth and rapid maturation, resulting in overall shorter production time (Bhardwaj, 2013).

Most sunflower cultivars have a short-day flowering response, which means the longer days of summer delay flowering, allowing plants to produce more leaves and increase stem length (Dole & Wilkins, 2005). As expected, in this experiment, the earliest planting date, 19 Mar., had the smallest stem diameter, indicating that the plants initiated flowering relatively quickly. Interestingly, while the plants from the later sowings likely had delayed flower initiation, more leaves per stem, and greater height, crop time was shorter due to increased summer temperatures and longer day lengths. Leaf total chlorophyll contents were similar for all treatments with numerical superiority of nutritional regimes over control (data not presented).

Proper planting methods are critical for the growth and production of high-quality cut stems. Tallest plants (105 cm) when planted on ridges with stem diameter (15.4 mm) and flower diameter (14.2 cm). Ridges promoted better soil aeration, root development, and water drainage, leading to accelerated plant growth and quality compared to other planting methods. The growth, quality and production of cut flowers are all affected by planting density. Sunflower produced harvestable stems in fewest days (40 d), when planted at 30×30 cm apart compared to 15×15 cm, which is in contrast with results given by Karuppaiah & Krishna (2005), who found that higher planting density of French marigolds (*Tagetes patula*) delayed flowering. Sunflower produced tallest plants (120 cm) when planted 15×15 cm apart, which is in line to the conclusions of Kapczynska (2013) and Suzer (2011), they found that plant height increased in proportion to the number of plants per square meter. Rajcan & Swanton (2001) attributed this behavior to a survival strategy based on the competition for light. Plants respond to environmental and management interventions by undergoing changes in their architectural and structural modifications (Sher *et al.*, 2018). Sunflowers that were planted with a spacing of 30×30 cm exhibited the largest stem and flower diameter, as well as the highest levels of chlorophyll content and leaf area. This study supports the findings of Bhosale *et al*. (2012), who suggested that a spacing of 30 × 30 cm is optimal for achieving the maximum flower diameter in cut gerbera. In the case of lily (*Lilium hybrids*) and tuberose (*Polianthes tuberosa*) bulbs, planting them with a spacing of 22.5 cm resulted in a greater number of high-quality stems for the market compared to spacings of 7.5 cm and 15 cm (Ahmad *et al*., 2019).

Plant nutrition is one of the most important factors to consider during cut flower production. Tallest plants (83 cm) occurred with the use of NPK + isabion, which also had the shortest production time (40 d) and longest vase life (8 d). These results suggested that optimal dose of macronutrients along with biostimulant application contributed towards better performance of cut sunflower. NPK + micronutrients, NPK + isabion and NPK + humic acid exhibited highest leaf N, P and K contents (%). Nitrogen is the most crucial plant nutrient due to its role as a main constituent of protein and nucleic acid, which facilitates rapid growth. Increased nitrogen levels improved plant nitrogen concentration as a result of excessive nitrogen supply and improved plant absorption. The results are consistent with previous research on tuberose, which showed that higher nitrogen levels had a notable impact on the nitrogen content of leaves. Additionally, the use of nitrogen, phosphorus, and potassium fertilizers boosted the longevity of the flowers (Borah *et al*., 2012; Khalaj *et al*., 2012). Applying NPK on stock (*Matthiola incana*) resulted in an increase in the levels of nitrogen (N), phosphorus (P), and potassium (K) in the leaves, as seen in a study conducted by Sarwar et al. in 2013. The results were consistent with previous research that showed a significant increase in the vase life of cut flowers when $FeSO_4$ was applied to the leaves before harvest, either alone or when combined with 1% $ZnSO_4$ (Amir *et al*., 2008).

The sunflower cultivars were quite different in their growth and vase life. 'Tall Red Sun' plants were the tallest (137.8 cm). 'Teddy Bear' and 'Tall Red Sun' both had the longest production time (61.2 d and 51.5 d, respectively). The shortest production time (43 d) was recorded for 'Vincent Choice', which might be due to variable response of cultivars to environmental factors like day length/ duration (Blaine, 1999). Stem length of most of the examined sunflower cultivars was also greatly influenced by day length and temperature.

Conclusion

Sunflower 'Vincent Choice' sown in May, transplanted on ridges or raised beds at a spacing of 15×15 cm, and supplied with NPK + isabion (0.4%) led to the shortest production time and best quality cut stems with a long vase life.

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