Hue University Journal of Science: Natural Science
Vol. 131, No. 1B, 19–28, 2022

pISSN 1859-1388
eISSN 2615-9678

Influence of nitrogen level and plant density on growth parameters and economic efficiency of sunflower cultured in Thua Thien Hue province

Hai Thi Hong Truong*, Thao Thu Phan

Institute of Biotechnology, Hue Univeristy, Road 10, Phu Thuong, Phu Vang, Thua Thien Hue, Vietnam

* Correspondence to Hai Thi Hong Truong <tthhai@hueuni.edu.vn>

(*Received: 5 March 2021; Accepted: 19 January 2022*)

Abstract. Sunflower (*Helianthus annuus*) cultivation is gaining popularity among Vietnamese farmers. Two separate experiments were conducted from January to April 2018 in a randomized complete block design with three replicates. Four levels of each factor were included in the experiments: 0, 20, 40, and 60 kg/ha for nitrogen and 11, 13, 16, and 20 plants/m^2 for the density. The nitrogen fertilizer (up to 60 kg/ha) substantially affects the leaf area, diameters of stem plant, receptacle and flower head, and cut flower vase life. Low plant density works well on plant height, leaf number, width and length at the flowering stage, with the largest head diameter (17.2 cm) at the 13 plants/m^2 density. Based on the results of both growth ability and economic efficiency, we suggested applying N at 60 kg/ha and planting at 16 plants/m^2 density for growing F1 cut sunflowers in Thua Thien Hue province.

Keywords: sunflower, nitrogen fertilizer, plant density, vase life, economic efficiency

1 Introduction

Sunflower (*Helianthus annuus* L.) is grown for various purposes, such as seed and oil, pot and cut flowers, husbandry feeding materials, or green manure [1-3]. In Vietnam, sunflower has widely been cultivated in Nghe An and other provinces, such as Lam Dong, Ha Noi, Bac Ninh, and the central areas, primarily for feeding materials, achene harvest, and floral photography. Sunflower is also favoured as cut or pot flowers because of their big inflorescent diameter and golden petals. Recently, sunflower has been introduced for trial cultivation in Thua Thien Hue to study the potential of local farming conditions. Cultural methods, including fertilizer application and cultivated density, should be investigated to improve culture practices.

Applying nutrition is one of the most crucial factors influencing plant growth and yield. Among all plant nutrients, nitrogen (N) is an essential macronutrient and plays a vital role in plant cell formation and division [4]. Nitrogen increases the plant height, head diameter, husk percentage, and seed and oil yields [2, 3, 5]. However, information regarding the impact of this important nutrient on sunflower cultivation is less available in Vietnam.

An optimum plant density is another important factor that affects the sunflower yield [6]. Plant density significantly affects various cut flowers, such as gerbera [7], chrysanthemum [8], and single-stemmed rose [9]. Most previous studies targeted the optimum plant density for maximum achene, oil content, and protein yield. There is less information on the cut flower yield of sunflowers in the literature [5, 10].

Therefore, this study investigates the optimum N level and plant density on the cut flower yield and economic efficiency of sunflower

cultivation in the Spring–Summer season in Thua Thien Hue province.

2 Materials and methods

2.1 Experimental conditions

A commercial F1 of sunflower (obtained from SAKATA Seed Corporation) was used in this study. Field experiments were conducted in the Institute of Biotechnology, Hue University, from January to April 2018. The soil type was sandy loam. The experiments were laid out in a randomized complete block design with four treatments and three replicates. The total area of each experiment was 96 m^2, and plot size was 8 m^2.

2.2 Experimental design

Experiment 1. Effect of the nitrogen level on growth parameters and economic efficiency of sunflowers

The experiment was conducted with four levels of N: 0, 20, 40, and 60 kg/ha. Before applying the nitrogen fertilizer, 500 kg/ha of lime was used to disinfect the soil from fungal diseases. Sideband application included 15 tons/ha of manure, 90 kg/ha of P_2O_5 and 20 kg/ha of K_2O before sowing. The first top-dressing was applied to plants at the 2-4 leaf stage with one-third of the total N amount. The second top-dressing was applied 30 days after sowing with the second third and 40 kg/ha of K_2O. The remaining N was supplied at flower head initiation. The plant density was 11 plants/m^2.

Experiment 2. Effect of plant density on growth parameters and economic efficiency of sunflowers

In this experiment, four plant densities (row × plant spacing) were adopted: 11 plants/m^2 (30 × 30 cm) as a control, 13 plants/m^2 (25 × 30 cm), 16 plants/m^2 (20 × 30 cm), and 20 plants/m^2 (20 × 25 cm). Sideband fertilizer application was carried out before sowing with 15 tons/ha of manure, 90 kg/ha of P_2O_5, 20 kg/ha of N, and 20 kg/ha of K_2O. The first top-dressing was applied with 20 kg/ha N at the 2-4 leaf stage, and then the last top-dressing was applied with 20 kg/ha of N and 40 kg/ha of K_2O at flower head initiation.

2.3 Data collection and analysis

Ten plants were randomly selected in each experiment for data collection. The time for germination, flower-budding, and flowering was determined when the performance in each stage reached 50%. The first cotyledons indicate germination. The plant height is the distance from the ground to the top apical meristem and was collected after every ten days. The total number of fresh leaves was counted every week. The average leaf area (cm^2/leaf) was calculated from five randomly selected leaves (0.47 × length × width/5). When the flowers opened widest, they were cut, and the flower head and receptacle diameters were measured. The yield is the total number of flowers per plot. The vase life is the time in days from harvesting until wilting. The rate of disease and number of insects were calculated from Eq. 1 and Eq. 2.

Rate of disease (%) = (Number of infected plants)/(Total number of selected plants) × 100 (1)

Density of insects (Number of insects/m^2) = (Total of insect number)/(Total experimental area) (2)

The profit of cut flowers was calculated according to Eq. 3. The mean values were estimated with MS Excel, and the analysis of variance was run with the Statistix software, version 10.0.

Profit (million dong/ha) = (Actual yield/ha × 2500 dong) – Capital spending/ha (3)

pISSN 1859-1388
eISSN 2615-9678

2.4 Weather conditions

Weather data were obtained from the Hydrometeorological Forecasting Center of Thua Thien Hue and presented in Table 1. The temperature was the lowest in February (19.3 °C) and the highest in April (24.7 °C). The rainfall was the highest in April (208.1 mm with 11 rainy days) and the lowest in March (20.8 mm with six rainy days). The sunshine time was the longest in March, with 156 hours.

3 Results and discussion

3.1 Effect of nitrogen level on growth parameters and economic efficiency

Most of the seeds (>90%) germinated within five to six days after sowing (DAS) (Table 2). The time from sowing to budding, flowering, and harvesting was the shortest at the 60 kg/ha N dose and the longest in the plot without N application. Although the changes in these values were small, the sunflower speed growth tended to increase when the N levels increased.

Table 1. Weather conditions during the Spring – Summer season 2018 in Thua Thien Hue

Month (2018)	Temperature (°C)			Mean relative humidity (%)	Rainfall (mm)		Sunshine time (hour)
	Mean	Maximum	Minimum		Rainy time (days)	Rainfall (mm)	
January	20.3 *	32.8	13.2	93	23	160.3	42
February	19.3	29.3	12.2	90	12	47.7	88
March	23.0	35.5	16.1	88	6	20.8	156
April	24.7	36.6	16.0	77	11	208.1	79

** Data was obtained from the Hydrometeorological Forecasting Center of Thua Thien Hue*

Table 2. Influence of different nitrogen levels on time to finish growth periods of sunflower

Nitrogen level (kg/ha)	Percentage of germination (%)	Time to germination (days)	Time to budding (days)	Time to flowering (days)	Time to harvesting (days)
0	95.8	5	44.6	55	64.7
20	93.1	5	42.5	53.2	63.1
40	95.8	5	42.4	52.6	62.9
60	90.3	6	42.1	52.1	62.2

Application of N had significant effects on agronomic attributes of sunflower. From 25 to 55 DAS, an increasing amount of N application increased the plant height (Table 3). The height of the sunflower plants grown in the 60 kg/ha treatment is the most significant (162.2 cm). They were 11 cm higher than the control. The results are consistent with those reported by Olowe et al. when sunflowers were applied with N at 60 and 90 kg/ha [11]. The nitrogen level, however, did not affect the leaf number among the treatments during the flowering stage (55 DAS). The stem and canopy diameters were the largest in the 60 kg/ha treatment and smallest in the control for 25, 45 and 55 DAS. At the early growth stage (15 DAS), the plant height, leaf number, stem diameter, and canopy diameter did not change much with different amounts of N fertilizer. The leaf area increased significantly when the level of N increased at the flower-budding stage. Still, the effect between the 20 and 40 kg/ha N treatments at 55 DAS was unnoticeable (Fig. 1). The leaf area in the 60 kg/ha treatment was the largest and significantly different from that of the others. A low nitrogen dose could lead to a low abscisic acid content in leaves, thus reducing the leaf area [12, 13].

Table 3. Influence of different nitrogen levels on agronomic characteristics of sunflower

	Nitrogen application (kg/ha)	**Days after sowing**				
		15	**25**	**35**	**45**	**55**
Plant height	0	7.8a[y]	16.5[c]	66.7[c]	100.3[c]	151.2[b]
	20	7.8[a]	17.7[b]	69.9[b]	104.4[b]	158.8[a]
	40	7.6[b]	18.3[b]	71.4[ab]	108.7[a]	160.5[a]
	60	7.7[b]	19.3[a]	72.9[a]	111.5[a]	162.2[a]
	LSD0.05	0.1	0.8	2.3	3.6	5.7
Leaf number	0	2.1[a]	12.2[b]	21.2[b]	27.4[b]	31.7[a]
	20	2.0[a]	12.3[b]	21.4[a]	27.5[b]	31.8[a]
	40	2.0[a]	12.2[b]	21.1[c]	27.8[ab]	32.4[a]
	60	2.0[a]	12.5[a]	21.4[a]	28.3[a]	31.6[a]
	LSD0.05	0.12	0.21	0.1	0.7	1.2
Stem diameter	0	0.3[a]	0.9[b]	1.3[b]	1.5[c]	1.6[b]
	20	0.3[a]	1.0[a]	1.4[b]	1.6[b]	1.6[b]
	40	0.3[a]	1.0[a]	1.4[a]	1.6[a]	1.6[b]
	60	0.3[a]	1.1[a]	1.4[a]	1.6[a]	1.8[a]
	LSD0.05	0.02	0.1	0.0	0.0	0.2
Canopy diameter	0	7.7[c]	27.7[d]	86.1[a]	103.3[a]	108.2[a]
	20	8.2[b]	30.2[c]	91.5[a]	108.2[a]	108.1[a]
	40	8.2[b]	31.4[b]	86.8[a]	108.1[a]	110.6[a]
	60	8.6[a]	34.0[a]	88.9[a]	110.5[a]	118.6[a]
	LSD0.05	0.2	0.9	11.8	10.7	11.3

Note: [y] Different letters in each column indicate significant differences among treatments in each growth parameter at $p \leq 0.05$.

pISSN 1859-1388
eISSN 2615-9678

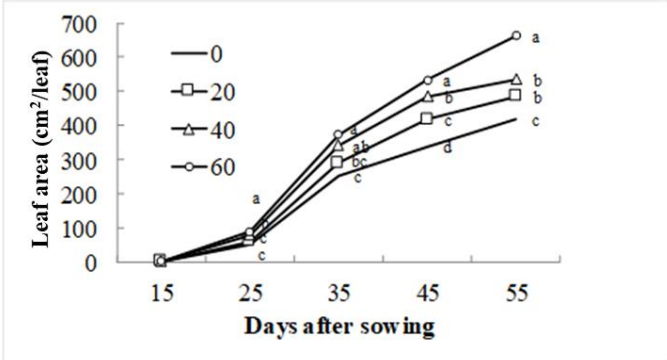

Fig. 1. Progress of leaf area of sunflower
(Different letters indicated significant differences of mean values among treatments).

The flower head and receptacle diameters also increased with the amount of N fertilizer (Fig. 2). The largest flower diameter (>17 cm) was observed in the 60 kg/ha treatment. In contrast, the smallest (14 cm) was found in the control treatment. The quantity of applied N also significantly affected the vase life, indicating the longest vase life. This life was 9.4 days for the plants grown in 60 kg/ha N as opposed to 7.2 days for the plants grown in the control treatment (Fig. 2). This vase life was acceptable for the market because other sunflower cultivars have their vase life ranging from 6.8 to 11.2 days [14]. The vase life correlated with the stem length and physiological changes [15]. Therefore, the quantity of N markedly affected the post-harvest quality of cut flowers.

Although the 60 kg/ha N treatment provided the best flower quality, it caused the appearance of diseases and insects (Table 4). The stalk rot was the most widespread among the diseases, and the insects were primarily green worms, grey worms, and pentatomidae. The highest brown eyespot rate was observed with the 40 kg/ha N dose (22%), whereas the lowest was in the control treatment (13%).

Table 5 shows the yield and economic value of cut sunflowers. The highest yield was achieved in the 60 kg/ha N treatment with 109.3 thousand cut flowers per hectare, leading to the highest profit of 464 million VND per hectare. Sunflowers grown in soil without N showed the lowest profit (403 million VND per hectare). Thus, the quantity of N supplied at 60 kg/ha resulted in good growth ability of sunflower and high profit for cut flower trading.

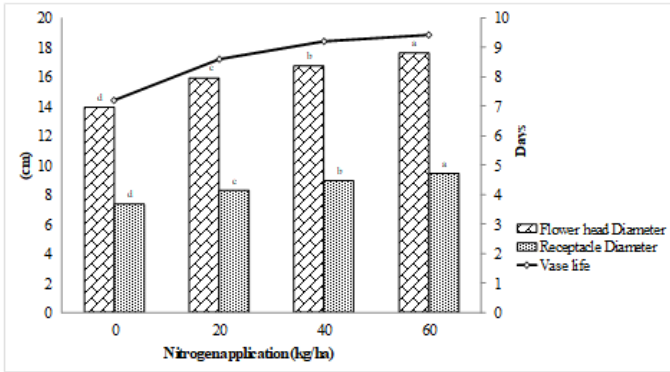

Fig. 2. Effect of nitrogen levels on flower head diameter, receptacle diameter and flower vase life of sunflower.
(Different letters indicated significant differences of mean values among treatments).

Table 4. Influence of different nitrogen levels on insect and disease damage

Nitrogen application (kg/ha)	Disease		Insect		
	Brown eyespot rate (%)	Stem rot rate (%)	Green worm (individual/m²)	Grey worm (individual/m²)	Pentatomidae (individual/m²)
0	18.0	0.0	4.7	2.7	0.0
20	19.0	3.3	5.3	3.3	0.0
40	22.1	0.0	7.0	5.3	0.7
60	13.2	6.7	10.6	7.3	1.0

Table 5. Influence of different nitrogen levels on the economic values of sunflower cultivation as cut flower

Nitrogen level application (kg/ha)	Cut flower yield (thousand/ha)	Total gross margin (million VND/ha)	Costs (million VND/ha)	Profit (million VND/ha)
0	92.0	644.200	241.100	403.100
20	99.0	693.300	258.000	435.300
40	103.1	721.800	263.800	458.000
60	109.3	765.200	301.200	464.000

3.2 Effect of plant density on growth parameters and economic efficiency

The germination time was 6–7 days after sowing, and the germination rate was higher than 94% in all treatments (Table 6). The time from sowing to flower head initiation ranged between 40 days (in 20 plants/m² and 16 plants/m²) and 42 days (in 11 plants/m²). Most plants produced flowers on the 53rd day after sowing. The time from sowing to harvesting was shortest in the 16 plants/m² treatment (59 days) and longest in the 11 plants/m² treatment (61 days). These results indicated that plant density did not affect the growth of sunflowers.

Table 6. Influence of plant densities on time to finish growth periods of sunflower

Plant density (plant/m²)	Percentage of germination (%)	Time to germination (days)	Flower head initiation (days)	Time to flowering (days)	Time to harvesting (days)
11	94.7	6	42	54	61
13	95.7	7	40	53	60
16	96.8	6	40	53	59
20	95.8	6	41	53	60

pISSN 1859-1388
eISSN 2615-9678

The plant height fluctuated significantly among treatments. The difference was from 1 to 9 cm within each period in the density treatments (Table 7). On the 15th DAS, the plant height was smallest (8.8 cm) at the 11 plants/m^2 density and largest (10.4 cm) at the 20 plants/m^2 density. On the 55th DAS, it was 163.5 cm (largest) at the 13 plants/m^2 density and 157 cm (smallest) at the 11 plants/m^2 density. The sunflowers growing at the lowest density (11 plants/m^2) had the tallest plants, and their height was significantly different from that of the others during the vegetative stages and at the beginning of the reproductive stage (25, 35 and 45 DAS). However, the plant heights at the flowering time (55 DAS) for the 20 plants/m^2, 16 plants/m^2, and 13 plants/m^2 densities were larger than 160 cm. At a lower plant density (85,000 plants/ha), several cultivars had a plant height under 150 cm [16]. The leaf number was not much influenced by the plant density. It ranged from 2.0 (16 plants/m^2) to 2.3 leaves (13 plants/m^2) on the 15th DAS and from 31.6 (11 plants/m^2) to 33.4 leaves (20 plants/m^2) on the 55th DAS. The leaf width and length were substantially different among treatments. On the 55th DAS and at the 20 plants/m^2 density, the widest leaf did not differ significantly from that at the 16 plants/m^2 and 13 plants/m^2 density. At the same time, the longest leaf (48.2 cm) was found at the 16 plants/m^2 density, and the length was significantly larger than at the other densities. Regarding leaf growth, the density did not affect the leaf area [1]. Thus, there are the least significantly differences among of leaf number, leaf width, and leaf length between treatments in each period.

Table 7. Influence of different plant densities on agronomic characteristics of sunflower

	Plant density (plant/m^2)	Days after sowing				
		15	25	35	45	55
Plant height (cm)	11	8.8b ^{y}	18.0^a	68.4^a	107.1^a	157.0^b
	13	8.9^b	16.4^b	67.9^a	100.4^{bc}	163.5^a
	16	9.2^b	17.4^{ab}	67.3^a	98.9^c	161.3^b
	20	10.4^a	16.9^{ab}	65.3^b	100.7^b	161.7^a
	LSD 0.05	0.5	1.2	2.3	1.6	3.2
No. of leaf	11	2.1^a	12.4^{ab}	21.9^b	28.0^a	31.6^a
	13	2.2^a	12.1^b	22.8^a	27.2^{ab}	32.0^a
	16	2.0^a	12.2^{ab}	21.7^b	27.1^{ab}	32.3^a
	20	2.1^a	12.6^a	21.0^c	27.0^b	33.4^b
	LSD 0.05	0.9	1.9	0.6	1.0	0.3
Leaf width (cm)	11	3.0^a	6.0^b	17.1^a	20.0^{ab}	20.0^b
	13	3.1^a	7.3^a	16.9^a	20.3^a	20.7^a
	16	2.7^b	7.6^a	16.6^a	18.6^b	20.9^a
	20	3.3^a	7.1^a	16.8^a	19.3^{ab}	21.8^a
	LSD 0.05	0.2	0.6	1.7	1.6	1.8
Leaf length (cm)	11	3.6^{ab}	15.3^a	34.0^a	37.4^a	45.0^b
	13	3.4^b	15.1^a	33.2^b	38.6^a	45.7^b
	16	3.4^b	15.0^a	32.8^b	37.7^a	48.2^a
	20	3.9^a	15.3^a	33.9^a	37.8^a	45.8^b
	LSD 0.05	1.5	3.3	0.7	1.8	0.3

Note: ^{y} Different letters in each column indicate significant differences among treatments in each growth parameter at $p \leq 0.05$.

In this research, the plant density affected the flower quality, such as head diameter, but not receptacle diameter and vase life (Table 8). At lower plant densities, the flower head diameter was larger. The largest flower head diameter (17.2 cm) was found at the 13.3 plants/m^2 density and significantly larger than that at the 20 plants/m^2 (15.9 cm) and 16.7 plants/m^2 (15.8 cm) density (Table 4). This trend was also reported by Holt and Campbell [16] when the increase in head diameter followed the decrease in the sunflower plant density [16]. It seemed that plants grown at lower density received more sunlight [10]. The vase life ranged from 6.8 to 9.0 days, but there was no significant difference among treatments

The weather in the Spring – Summer season could be suitable for the pests and diseases to spread. The rate of brown eyespot was the highest (30.3%) at the 20 plants/m^2 density, followed by the 13 plants/m^2 density with a rate of 20.3% (Table 9). The stalk rot rate was low at the 13 plants/m^2 (3.1%) and 11 plants/m^2 (6.7%) density. Green worms were detected from 2.3 (16 plants/m^2) to 5.5 (11 plants/m^2) individuals/m^2. The sunflowers grown at the 16 plants/m^2 density were less influenced by disease and insects than the others. The highest yield (115 thousand cut flowers/ha) was obtained at the 16 plants/m^2 density, followed by the 20 plants/m^2 density at 112.50 thousand cut flowers/ha (Table 10). The profit of cut flowers was also the highest at the 16 plants/m^2 density at 158 million VND per hectare. In this experiment, sunflowers should be grown at the 16 plants/m^2 density to achieve the highest cut flower yield and least harmed by pests and disease.

Table 8. Influence of different plant densities on quality of cutting sunflower

Plant density (plant/m^2)	Receptacle diameter (cm)	Flower head diameter (cm)	Vase life (days)
11	6.4^a	16.3^{ab}	7.0^a
13	6.4^a	17.2^a	7.0^a
16	6.4^a	15.8^b	6.8^a
20	6.4a ^{y}	15.9^b	6.9^a
LSD 0.05	0.35	1.33	0.32

Note: ^{y} Different letters indicated a significant difference of mean values among treatments at $p \leq 0.05$.

Table 9. Influence of different plant densities on pest and disease damage of sunflower

Plant density (plant/m^2)	Disease		Insects		
	Brown eyespot rate (%)	Stem rot rate (%)	Green worm (individual/m^2)	Grey worm (individual/m^2)	Pentatomidae (individual/m^2)
11	10.6	6.7	5.5	1.9	3.0
13	20.3	3.1	3.4	3.2	1.5
16	10.7	0.0	2.3	0.6	1.6
20	30.3	0.0	4.3	2.0	2.1

pISSN 1859-1388
eISSN 2615-9678

Table 10. Effect of plant density on the economic values of sunflower cultivation as cut flower

Plant density (plant/m²)	Cut flower yield (thousand/ha)	Total gross margin (million VND/ha)	Costs (million VND /ha)	Profit (million VND/ha)
11	86.25	215.625	126.000	89.625
13	101.25	253.125	128.000	125.125
16	115.00	287.500	129.000	158.500
20	112.50	281.250	131.500	149.750

4 Conclusion

In this study, the effects of nitrogen application and plant density on the growth and flowering of F1 sunflowers were investigated. Based on the results, we concluded that the increase in nitrogen application could promote the growth and flowering of sunflowers while plant density did not affect these parameters. We suggest that nitrogen at the 60 kg/ha dose and the 16 plants/m^2 density be applied to cultivation in other seasons with different cultivars to evaluate their impacts.

References

1. Steer BT, Coaldrake PD, Pearson CJ, Canty CP. Effects of nitrogen supply and population density on plant development and yield components of irrigated sunflower (*Helianthus annuus* L.). F Crop Res. 1986;13(C):99-115.
2. Zubillaga MM, Aristi JP, Lavado RS. Effect of phosphorus and nitrogen fertilization on sunflower (*Helianthus annus* L.) nitrogen uptake and yield. J Agronomy & Crop Science. 2002;188:267-274.
3. Munir MA, Malik MA, Saleem MF. Impact of integration of crop manuring and nitrogen application on growth, yield and quality of spring planted sunflower (*Helianthus Annuus* L.). Pakistan J Bot. 2007;39(2):441-9.
4. Scott P. Physiology and behavior of plants. Singapore: John Wiley and Sons; 2008. Chapter 5, Mineral nutrition of plants; p. 75-87.
5. Hussain M, Farooq M, Shehzad M, Khan MB, Wahid A, Shabir G. Evaluating the performance of elite sunflower hybrids under saline conditions. Int J Agric Biol. 2012;14(1):131-5.
6. Robinson RG, Ford JH, Lueschen WE, Rabas DL, Smith LJ, Warnes DD, et al. Response of sunflower to plant population. Agron J. 1980;72(6):869-71.
7. Dufault RJ, Phillip TL, Kelly JW. Nitrogen and potassium fertility and plant populations influence field production of gerbera. HortScience. 1990;25(12):1599-602.
8. Carvalho SMP, Heuvelink E, Van Kooten O. Effect of light intensity, plant density, and flower bud removal on the flower size and number in cut chrysanthemum. Acta Hortic. 2002;593:33-8.
9. Bredmose NB. Growth, flowering, and postharvest performance of single-stemmed rose (*Rosa hybrida* L.) plants in response to light quantum integral and plant population density. J Amer Soc Hort Sci. 1998;123:569-76.
10. Diepenbrock W, Long M, Feil B. Yield and quality of sunflower as affected by row orientation, row spacing and plant density. Bodenkultur. 2001;52(1):29-36.
11. Olowe VI, Adebimpe OA, Obadiahi TE. Response of sunflower (*Helianthus annuus* L .) to nitrogen and phosphorus application in the forest-savanna transition zone of south west. Niger J Hort Sci. 2005;10:23-9.
12. Chapin FS, Walter CHS, Clarkson DT. Growth response of barley and tomato to nitrogen stress and its control by abscisic acid, water relations and photosynthesis. Planta. 1988;173(3):352-66.
13. Palmer SJ, Berridge DM, Mcdonald AJS, Davies WJ. Control of leaf expansion in sunflower (*Helianthus annuus* L.) by nitrogen nutrition. 1996;47(296):359-368.
14. Yañez P, Ohno H, Ohkawa K. Photoperiodic response and vase life of ornamental sunflower cultivars. Horttechnology. 2005;15(2):386-90.

15. Mensuali-Sodi A, Ferrante A. Physiological changes during postharvest life of cut sunflowers. Acta Hortic. 2005;669:219-24.

16. Holt NW and Campbell SJ. Effect of plant density on the agronomic performance of sunflower on dryland. Can J Plant Sci. 1984;64:599-605.