Central Asian Journal of Plant Science Innovation **2** (2021) 102–108

RESEARCH PAPER

Sunflower (*Helianthus annuus* L.) grain yield affected by fertilizer and plant density

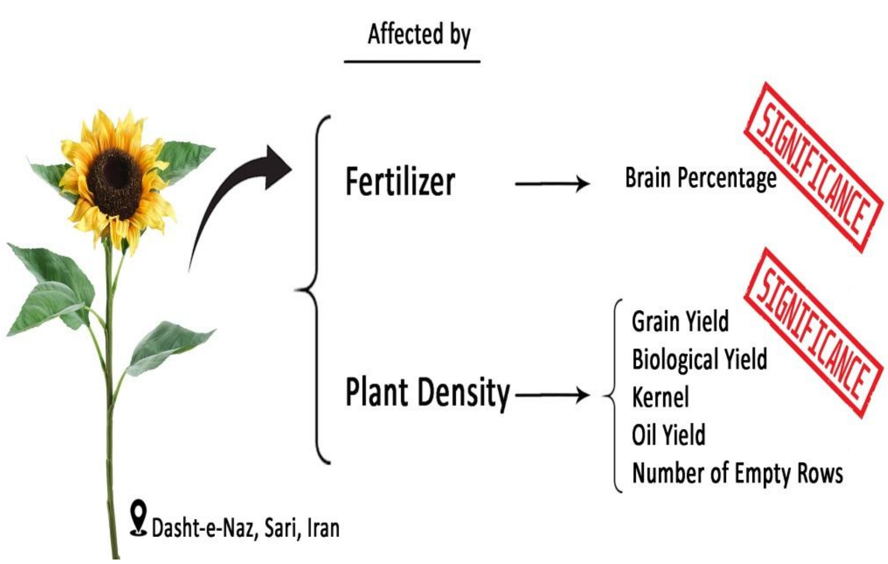
Hamed Modanlo [1], Mehdi Baghi [1], Abbas Ghanbari Malidarreh [2*]

[1] Department of Agronomy, Rodehen Branch, Islamic Azad University, Rodehen, Iran
[2] Department of Agronomy, Jouybar Branch, Islamic Azad University, Jouybar, Iran

Highlights

- Grain and oil yields had significant differences by plant density and there was a significant difference in the effect of fertilizer only on the grain kernel ratio.
- Cultivar Master of sunflower should be sown in high plant density with fertilizer application $N_{69}P_{75}K_{75}$was obtained the maximum grain and oil yields.
- In the condition of low plant density, because being of enough nutrients sinks was a limitation and in the condition of high plant density, the source was a limitation that decrease of yield component indicates.

Graphical Abstract



Article Info

Receive Date: 12 December 2020
Revise Date: 25 April 2021
Accept Date: 28 May 2021
Available online: 13 June 2021

Keywords:
Biological yield
Fertilizer
Oil yield
Plant density
Sunflower

Abstract

In order to study the effect of fertilizer and crop density on some agronomic traits in sunflower, a field experiment was carried out as a split-plot based on randomized complete block design with three replications in the Agricultural Research Farm of Dasht-e-Naz in Sari, Iran. Main plots included four fertilizer treatments ($N_0P_0K_0$, $N_{23}P_{25}K_{25}$, $N_{46}P_{50}K_{50}$ and $N_{69}P_{75}K_{75}$) and sub-plots included four plant densities (D_{50}= 50000, D_{60}= 60000, D_{70}= 70000, and D_{80}= 80000 plant ha^{-1}). The results indicated that there was a significant difference in grain yield, biological yield, kernel, and oil yield ($P< 0.01$) and individual biological yield and the number of empty rows ($P< 0.05$) by plant density. There was a significant difference in grain kernel ratio ($P< 0.05$) by fertilizers. F_2 and F_1 had the maximum and minimum grain kernel ratio with 77.40 and 76.30%, respectively. D_{50} and D_{80} had the lowest and highest grain yield with 5666 and 3633 kg/ha, respectively. Biological yield in D_{60} was the lowest but in D_{80} was the highest with 10853 and 16460 kg/ha, respectively.D_{60} and D_{50} had the lowest and highest individual biological yield with 180.90 and 225.90 g/plant, respectively. The maximum and minimum grain yield was obtained in F_3 (4817 kg/ha) and F_2 (3968 kg/ha), respectively.

10.22034/CAJPSI.2021.02.05

E-ISSN: 2783-1310

* Corresponding author: aghanbarym@yahoo.ca (A. Ghanbari Malidarreh)

1. Introduction

Sunflower (*Helianthus annuus* L.) is an important oil crop in the world; its cultivation is becoming widespread. Sunflower combines high yield with great adaptation capacity, the characteristically high photosynthetic capacity and harvest index makes this crop viable for contrasting environments (Agele et al., 2007). The post rainy season period offers a unique cropping opportunity for sunflower in the humid zone in the north of Iran. However, the post rainy season is characterized by concurrent stresses due to extremely high soil and air temperatures, solar intensity and vapor pressure deficits and severe soil moisture deficits. Soil water reserve is a valuable resource important to the exploitation of the potentials offered by the post rainy season cropping period. Iran has been facing a recurring shortage of vegetable oils for many years due to fluctuations in the production of oil-grain crops. Presently, over 90% of vegetable oil being consumed in Iran has to be imported.

The plant response to crowding includes plant elongation (height of growth) and leaf reorientation (Maddonni et al., 2001). The partitioning of biomass to grain is important to yield in crops including oil-grain crops (Agele et al., 2007). Killi, reported that a more dense sow (7.1-10 plant/m^2) as compared to a less dense sow (4.1-5.7 plant/m^2) could have resulted in an improvement in yield (30%) in hybrid oil-grain sunflower (Killi, 2004). It also reduces the leaf area index required to intercept 95% of the incident radiation due to an increase in the light extinction coefficient (Flénet et al., 1996). Some researchers reported grain yield increases (Porter et al., 1997; Ethredge et al., 1989), but others have not (Robinson, 1978; Zaffaroni and Schneiter, 1991; Blamey et al., 1997). Numerous research studies for different climates have shown that plant density influences the growth, grain yield and quality of sunflower. Schneiter and Miller, also suggested that increased plant density resulted in a significant increase in grain yield (Schneiter and Miller, 1981). Grain and oil yields and grain oil percentage were positively correlated with plant density, but plant height, head diameter, 100-grain weight and grain yield plant^{-1} all decreased with increasing plant density (Adamczewska-Sowińska and Uklańska, 2009). Thus, determining optimum management practices is likely to be of critical importance in different ecological conditions (Killi, 2004). Responses to increased stand density in crops are enhanced inter-plant competition and variability in phenotypic traits such as biomass, height, kernel number (Agele et al., 2007). Related to this are traits like compact canopy architecture (shorter plants), and a more balanced allometric relationship between the head and the grains, in addition to improved biomass partitioning from vegetative to reproductive structures (Vega et al., 2000). This feature could help to develop shade avoidance characteristics (Maddonni et al., 2001).

It is necessary to understand biological processes which are responsible for leaf reorientation and other plant behavior under competition in diverse crop species and agroecologies (Agele et al., 2007). Killi, indicated that plant height, head diameter, the total number of grains head, grain setting efficiency, grain yield head, 1000-grains weight, de-hulled grain ratio, grain oil content, grain and oil yield of confection sunflower, except de-hulled grain ratio of oil grain sunflower were significantly affected by plant population (Killi, 2004). The lowest plant populations (23800 plants/ha) resulted in the highest head diameter, the total number of grains head, grain yield head and 1000–grain weight while the highest plant populations (71420 plants/ha) resulted in the highest oil content, grain and oil yield in both varieties (Killi, 2004). The plasticity of a crop canopy based on leaf reorientation would contribute to maintaining a daily light interception nearly independent of inter-row distance (Agele et al., 2007).

The knowledge of crop physiological responses at high plant density is important for improving crop simulation models aimed at predicting NPK (Ritchie and Alargarswamy, 2003). Nitrogen fertilizer up to 150 kg/ha increased the grain yield and biological yield, whereas higher levels of N fertilizer decreased both yields in sunflower (Mojiri and Arzani, 2003). Nitrogen levels had significantly affected on the total number of grains head^{-1}, grain setting efficiency, grain yield head, 1000-grains weight, grain, and oil yield of sunflower. N_{60} treatment gave the highest grain yield (4.3 t/ha) and oil yield (1.7 t/ha). The previous study (Zubriski and Zimmerman, 1974) revealed that nitrogen reduced oil percentage of the grain. Nitrogen increases grain and oil yields by influencing several growth parameters such as grains per head and grain weight and by producing more vigorous growth and development. Also, excessive use of N fertilizer can decrease grain oil content. Nitrogen application at a rate of 120 kg/Nha gave the highest grain and oil yields/ha. The highest grain and oil yields were obtained with the application of 175 kg/Nha and a plant density of 80000 plants/ha (Adamczewska-Sowińska and Uklańska, 2009). Zubriski and Zimmerman, found that phosphorous fertilizer failed to increase grain yields in 10 of 12 trials and had little effect on the size of confectionery grains and oil concentration of oil-type grains (Zubriski and Zimmerman, 1974). Application of potassium increased the 1000-grain weight but no effect was seen on the plant height or the diameter of the plant stem. Robinson, reported that N application alone or in combination with P and K increased plant height (Robinson, 1978). Ahmad et al., found that K application significantly affected grain protein concentration of autumn sunflower but differences were non-significant in spring season crop (Ahmad et al., 2001). Chaudhry and Mushtaq, reported a slight to a significant reduction in grain protein concentration with K application as compared to control (Chaudhry and Mushtaq, 1999). Higher P levels increased the nitrogen use efficiency and yield (Zubillaga et al., 2002). Mojiri and Arzani, reported that deficiency of N, P, and K decreased grain yield of hybrid sunflower by 19.4, 15.3, and 22.7%, respectively (Mojiri and Arzani, 2003). This project was performed with the purpose of sunflower response to fertilizer combination in different plant densities on yield and yield components.

2. Material and Methods

The experiment was conducted to determine a suitable level of N, P, and K for sunflower (*Helianthus annuus* L. cv. Master) at the Agricultural Research Farm of Sari (53°11′ E, 36°37′ N 10 m altitude), Mazandaran, Iran. Some meteorological data at the site of the experiment are shown in Table 1. The soil characteristics are shown in Table 2.

Table 1. Some meteorological data at the site of the experiment during sunflower growth.

Variable	Apr.	May	June.	July	Aug.	Sep.
Min. temperature (°C)	11.4	14.2	18.8	21.9	23.5	22.7
Max. temperature (°C)	22.4	24.4	28.1	30.1	32.7	32.4
Mea. temperature (°C)	16.9	19.3	23.4	26	28.1	27.5
Min. relative humidity (mm/month)	51	54	50	54	53	51
Max. relative humidity (mm/month)	90	94	88	90	89	89
Mean relative humidity (mm/month)	70	73	69	72	71	70
Total rainfall (mm/month)	20.8	21.1	18.9	22.4	5.7	26.4

Table 2. Soil properties of the farm of Dashte-Naz during spring.

Soil texture	Sand (%)	Silt (%)	Clay (%)	pH	K (Mg/Kg)	P (Mg/Kg)	S (Mg/Kg)	N (%)	O.C (%)	EC Ds/m
Medium Loam	44	33	23	7.36	202	8	6.7	0.2	1.8	0.56

The experiment was conducted as a split-plot based on randomized complete block design with fertilizer levels as main plots and plant density as subplots that treatments were replicated three times. Four plant densities including (D_{50}= 50000, D_{60}= 60000, D_{70}= 70000 and D_{80}= 80000 Plant/ha) and four fertilizer treatments including ((F_0) $N_0P_0K_0$, (F_1) $N_{23}P_{25}K_{25}$, (F_2) $N_{46}P_{50}K_{50}$ and (F_3) $N_{69}P_{75}K_{75}$). The crop was sown on a well-prepared grain bed in 60 cm spaced rows using a single row hand drill. The whole of P and K along with half of N fertilizer in the form of superphosphate, potassium sulfur and urea were applied at sowing time, respectively and the remaining nitrogen was applied with flowering stage. Plants were thinned to one plant per hill in 25 days after sowing at the two to four-leaf stages. Sublot size was 5 m × 4 m. Biomass was oven-dried at 80 °C for 48 h and dry weight was recorded. Ten plants from each plot were randomly evaluated for plant height, total grain, empty row, grain setting efficiency. Achenes were separated into non-empty and empty. Non-empty achenes were counted, oven-dried (with air circulating at 60 °C) to constant weight, and weighed. Grain setting efficiency was calculated from nonempty and empty achenes as (nonempty achenes non-empty + empty achenes) × 100. Grain yield, kernel yield, grain kernel ratio and biological yield were obtained from an area 1.2 m wide and 3 m long of the center two rows of each plot. Grain samples were collected from each plot and ground with an electric coffee mill. A small portion of ground grains (5 g) was transferred to a disposable filter column and grain oil content was determined by the Soxhlet apparatus. In the experiment, harvesting commenced when all plants reached harvesting maturity, after physiological stage R-9 (Schneiter and Miller, 1981), the oilgrain sunflower cultivar was harvested by hand. Matured heads were harvested 16 weeks after planting and the grain yield per ton for each plot was also determined. Data collected from the field were analyzed (ANOVA) to determine the effect of treatments on the parameter measured using the MSTAT–C. Means and interactions were separated using Duncan multiple range test at level of 5%.

3. Results and Discussion

Grain and oil yields had significant differences by plant density ($P \leq 0.01$) (Table 3). So, the highest and lowest of grain and oil yields were from D_{80} and D_{50} with 5666, 3633 and 2698, 1791 kg/ha, respectively (Table 4). Grain yield of F_3 with 4817 kg/ha and F_2 with 3968 kg/ha was the maximum and minimum, respectively. Numerous research studies for different climates have shown that plant density influences the growth, grain yield and quality of sunflower. Grain and oil yields were positively correlated with plant density, but plant height, head diameter, 100-grain weight and grain yield/plant all decreased with increasing plant density (Adamczewska-Sowińska and Uklańska, 2009). Also, plant height was not a significant difference. Table 3 shows that there was a significant difference in the effect of fertilizer only on the grain kernel ratio ($P \leq 0.05$). So, the maximum and minimum of the grain kernel ratio were from F_2 and F_1 with 77.40 and 76.30 %, respectively (Table 4). Application of potassium increased the 1000-grain weight but no effect was seen on the plant height or the diameter of the plant stem. Kernel yield had a significant difference by the effect of the plant density ($P \leq 0.01$) (Table 3). So, the maximum and minimum kernel yield was from D_{80} and D_{50} with 4353.70 and 2810.30 kg/ha, respectively (Table 4). Related to this are traits like compact canopy architecture (shorter plants), and a more balanced allometric relationship between the head and the grains, in addition to improved biomass partitioning from vegetative to reproductive structures (Vega et al., 2000).

It is seen from Table 3 that the biological yield per plant was significantly different by the effect of the plant density ($P \leq 0.05$), so the maximum and minimum were from D_{50} and D_{60} with 225.90 and 180.90 g/plant, respectively (Table 4). It is necessary to understand biological processes responsible for leaf reorientation and other plant behavior under competition in diverse crop species and agroecologies (Agele et al., 2007). Biological yield per ha had a significant difference by the effect of the plant density ($P \leq 0.01$) (Table 3). So, the maximum and minimum of biological yield per ha were from D_{80} and D_{60} with 16460 and 10853 kg/ha, respectively. Responses to increased stand density in crops are enhanced inter-plant competition and variability in phenotypic traits such as biomass, height, kernel number, etc (Agele et al., 2007). It is seen from Table 3 that the number of empty rows was the significant difference by the effect of the plant density ($P \leq 0.05$), so the maximum and minimum were from D_{60} and D_{80} with 5.77 and 7.07, respectively (Table 4). Plant density-induced competition for assimilates or assimilate limitation during grain filling could cause kernel abortion due to low dry matter partitioning to reproductive sinks at flowering (Vega et al., 2000; Maddonni and Otegui, 2004). Overall, high plant density had increased plant height; because high plant density improves compatibility and space result in high vegetative growth; so that plant height of D_{50} with 174.70 cm was the lowest. The number of empty rows per head indicated that high and low plant density greatly decreases, that in the condition of low plant density because being of enough nutrients, sinks limitation and in the condition of high plant density was source limitation that decrease of yield component indicates them. But, there was no significant difference in the number of total grains per head by plant density, but empty percentage per head had a role of determinant and result in significantly grain yield.

Table 3. Means square of effect fertilizers and plant density on agronomic traits of sunflower in Iran.

S.O.V	DF	P.H	N.E.R	N.T.G	G.S.E	G.K.R	B.Y.P	B.Y.H	G.Y	K.Y	O.Y
Rep.	2	24.60 ns	4.00 ns	356.40 ns	77.33 ns	1.40 ns	287.30 ns	281385.00 ns	226875.00 ns	173189.90 ns	451393.00 ns
Fertilizer (F)	3	47.00 ns	1.20 ns	19208.60 ns	58.74 ns	2.70*	1571.70 ns	8747689.00 ns	14949020.00 ns	882546.30 ns	518312.00 ns
E (a)	6	323.80	2.10	45312.30	24.54	0.40	5907.50	27555310.00	1875910.00	1126326.80	818294.00
Density (D)	3	107.70 ns	5.00*	10205.20 ns	29.46 ns	0.10 ns	5662.80*	78097887.00**	97251103.00**	5695268.00**	2192994.00**
F×D	9	15.50 ns	1.90 ns	22700.70 ns	23.81 ns	5.30 ns	262890.00 ns	12499609.00 ns	819723.00 ns	501478.90 ns	363951.00 ns
E	24	88.30	1.90	19004.90	30.02	2.70	1238.00	6312893.00	742260.00	451407.50	267471.00
C.V. (%)	-	5.24	21.21	8.90	7.42	2.13	17.70	19.60	19.45	19.71	24.50

*, ** and ns show significance at 0.05, 0.01 probability levels and no significance, respectively. P.H: Plant height, N.E.R: Number of empty rows, N.T.G: Number of total grain, G.S.E: Grain setting efficiency, G.K.R: Grain kernel ratio, B.Y.P: Biological yield per plant, B.Y.H: Biological yield per hectare, G.Y: Grain yield, K.Y: Grain yield, O.Y: Oil yield.

Table 4. Comparison means of sunflower agronomic traits at plant density (D) and fertilizers (F) in Iran.

Treatments	N.E.R.H	G.K.R (%)	B.Y (g/plant)	B.Y (kg/ha)	G.Y (kg/ha)	K.Y (kg/ha)	O.Y (kg/ha)
F_0	6.52 a	76.90 a	185.10 a	11935.00 a	4528.00 a	3490.90 a	2180.00 a
F_1	6.52 a	76.30 b	198.50 a	12935.00 a	4398.00 a	3357.20 a	2035.00 a
F_2	6.54 a	77.40 a	197.20 a	12481.00 a	3968.00 a	3069.20 a	1869.00 a
F_3	5.92 a	77.30 a	213.10 a	13950.00 a	4817.00 a	3718.50 a	2357.00 a
D_{50}	5.95 ab	77.30 a	225.90 a	11296.00 b	3633.00 c	2810.30 c	1791.00 b
D_{60}	7.07 a	76.60 a	180.90 b	10853.00 b	3916.00 bc	2998.20 bc	1796.00 b
D_{70}	6.71 ab	77.00 a	181.20 b	12684.00 b	4498.00 b	3473.60 b	2156.00 b
D_{80}	5.77 b	76.90 a	205.86 ab	16460.00 a	5666.00 a	4353.70 a	2698.00 a

Values followed by the same letters are not significantly different at the 5% level by Duncan's multiple range tests. N.E.R.H: Number of empty rows per head, B.Y: Biological yield.

4. Conclusions

It can be concluded that cultivar Master of sunflower should be sown in high plant density (80000 plant/ha) with fertilizer application F_3 was obtained the maximum grain and oil yields. Overall, sunflower response was interest in plant density, although the number of total grains per head and number of empty rows per head was decreased by high plant density, grain yield was significantly increased because empty percentage per head was low. So, part of each plant had decreased in grain yield, but high plant density increase grain yield, therefore sunflower in high plant density with a suitable change of configuration benefit from the environment suitably, because traits were phototropism.

Biological yield per ha and plant indicate that in the low plant density increased product of each per plant, but biological yield per hectare was decreased. So, decreasing of biological yield was logical in plant density of D_{70} and D_{60}, but grain yield per ha in D_{80} had increased because plant density was optimum, that resulted in an increase of biological yield, but biological yield per ha was linear trend completely and increase, considering high grain yield, D_{80} was optimum plant density, while because smallness head is desirable maturity uniformity and also harvest. Fertilizer application had only a significant effect on grain kernel ratio, it seems that also has a specific trend and high fertilizer application increased grain kernel ratio, that it has been desirable. So, on the whole effect of fertilizer treatments that were compound three kinds of essential elements in different rates, in this research had not quantity influence of the study of agronomy traits clearly, that can relate to conditions of climate, soil, crop rotation, pre-planting, variety and etc. Oil and kernel yields that are two factors of importance in the production of final oil also had an increase with high plant density although were significant even, fertilizers application also increased grain yield that based on Duncan was in different levels, resulting in high oil and kernel yield. That high C.V. and low D.F. of fertilizer treatment can cause to high error and cause reason of non-significant statistically in the main factor of fertilizers. Finally, increase plant density results in increasing plant-to-plant competition and duo to reducing plant biomass while increase grain yield by increasing photosynthesis and high leaf area index.

References

Agele, S.O., Maraiyesa, I.O., Adeniji, I.A., 2007. Effects of variety and row spacing on radiation interception, partitioning of dry matter and seed set efficiency in late season sunflower (*Helianthus annuus* L.) in a humid zone of Nigeria. *Afr. J. Agr. Res.*, **2**(3), 80-88. https://doi.org/10.5897/AJAR.9000277

Ahmad, R., Saeed, M., Mahmood, T., Ullah, E., 2001. Yield potential and oil quality of two sunflower hybrids as affected by K application and growing seasons. *Int. J. Agri. Biol.*, **3**(1) 51-53.

Adamczewska-Sowińska, K., Uklańska, C.M., 2009. Effect of nitrogen fertilization on yield and quality of endive. *Veg. Crop. Res. Bull.*, **70**(1), 193-201. https://doi.org/10.2478/v10032-009-0019-6

Blamey, F.P.C., Zollinger, R.K., Schneiter, A.A., 1997. Sunflower production and culture. *Sunflower Technol. Prod.*, **35**, 595-670. https://doi.org/10.2134/agronmonogr35.c12

Chaudhry, A.U., Mushtaq, M., 1999. Optimization of potassium in sunflower. *Pak. J. Bio. Sci.*, **2**(3), 887-888. https://doi.org/10.3923/pjbs.1999.887.888

Ethredge Jr, W.J., Ashley, D.A., Woodruff, J.M., 1989. Row spacing and plant population effects on yield components of soybean. *Agron. J.*, **81**(6), 947-951. https://doi.org/10.2134/agronj1989.00021962008100060020x

Flénet, F., Kiniry, J.R., Board, J.E., Westgate, M.E., Reicosky, D.C., 1996. Row spacing effects on light extinction coefficients of corn, sorghum, soybean, and sunflower. *Agron. J.*, **88**(2), 185-190. https://doi.org/10.2134/agronj1996.00021962008800020011x

Killi, F.A.T.I.H., 2004. Influence of different nitrogen levels on productivity of oilseed and confection sunflowers (Helianthus annuus L.) under varying plant populations. *Int. J. Agric. Biol.*, **6**(4), 594-598.

Maddonni, G.A., Otegui, M.E., 2004. Intra-specific competition in maize: early establishment of hierarchies among plants affects final kernel set. *Field Crop. Res.*, **85**(1), 1-13. https://doi.org/10.1016/S0378-4290(03)00104-7

Maddonni, G.A., Chelle, M., Drouet, J.L., Andrieu, B., 2001. Light interception of contrasting azimuth canopies under square and rectangular plant spatial distribution: simulations and crop measurements. *Field Crops Res.*, **70**(1), 1-13. https://doi.org/10.1016/S0378-4290(00)00144-1

Mojiri, A., Arzani, A., 2003. Effects of nitrogen rate and plant density on yield and yield components of sunflower. *Isfahan Univ. Technol. J. Crop Prod. Process.*, **7**(2), 115-125. (In Persian)

Porter, P.M., Hicks, D.R., Lueschen, W.E., Ford, J.H., Warnes, D.D., Hoverstad, T.R., 1997. Corn response to row width and plant population in the northern corn belt. *J. Prod. Agric.*, **10**(2), 293-300. https://doi.org/10.2134/jpa1997.0293

Ritchie, J.T., Alagarswamy, G., 2003. Model concepts to express genetic differences in maize yield components. *Agron. J.*, **95**(1), 4-9. https://doi.org/10.2134/agronj2003.4000

Robinson, R.G., 1978. Production and culture. *Sunflower Sci. Technol.*, **19**, 89-143. https://doi.org/10.2134/agronmonogr19.c4

Schneiter, A.A., Miller, J.F., 1981. Description of sunflower growth stages. *Crop Sci.*, **21**(6), 901-903. https://doi.org/10.2135/cropsci1981.0011183X002100060024x

Vega, C.R.C., Sadras, V.O., Andrade, F.H., Uhart, S.A., 2000. Reproductive allometry in soybean, maize and sunflower. *Ann. Bot.*, **85**(4), 461-468. https://doi.org/10.1006/anbo.1999.1084

Zaffaroni, E., Schneiter, A.A., 1991. Sunflower production as influenced by plant type, plant population, and row arrangement. *Agron. J.*, **83**(1), 113-118. https://doi.org/10.2134/agronj1991.00021962008300010027x

Zubillaga, M.M., Aristi, J.P., Lavado, R.S., 2002. Effect of phosphorus and nitrogen fertilization on sunflower (Helianthus annus L.) nitrogen uptake and yield. *J. Agron. Crop Sci.*, **188**(4), 267-274. https://doi.org/10.1046/j.1439-037X.2002.00570.x

Zubriski, J.C., Zimmerman, D.C., 1974. Effects of Nitrogen, Phosphorus, and Plant Density on Sunflower. *Agron. J.*, **66**(6), 798-801.

How to cite this paper:
Modanlo, H., Baghi, M., Ghanbari Malidarreh, A., 2021. Sunflower (*Helianthus annuus* L.) grain yield affected by fertilizer and plant density. *Cent. Asian J. Plant Sci. Innov.*, **2**, 102-108.