Plant Archives Vol. 24, No. 2, 2024 pp. 2085-2095 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.301

RESPONSE OF PLANTING GEOMETRY, NITROGEN AND SULPHUR LEVELS ON GROWTH PARAMETERS AND YIELD OF SUNFLOWER (*HELIANTHUS ANNUS* L.)

Prakhar Rahangdale*, Ashwani Kumar Thakur and Ashwani Kumar

Department of Agronomy, S.G. College of Agriculture and Research Station, Jagdalpur, I.G.K.V., Raipur, Chhattisgarh - 494001, India.

*Corresponding author E-mail: prakharrahangdale82@gmail.com

(Date of Receiving-17-03-2023; Date of Acceptance-08-06-2024)

ABSTRACT

A field experiment was conducted at Shaheed Gundadhoor College of Agriculture and Research Station, Jagdalpur, IGKV, Raipur (C.G.), during *Rabi* season 2022-23, with a split plot design as an experimental framework. The treatments included three different planting geometry such as G1 (45 cm × 30 cm), G2 (60 cm × 30 cm) and G3 (75 cm × 30 cm) in main plot, two nitrogen levels *i.e.* N1 (60 kg ha^{-1}) and N2 (80 kg ha^{-1}) as sub plot and three sulphur levels, such as S1 (15 kg ha^{-1}), S2 (20 kg ha^{-1}) and S3 (25 kg ha^{-1}) in sub plot. The experiment findings revealed that significant differences were noticed among the different planting geometry, nitrogen and sulphur levels in sunflower crop. Among the planting geometry, 75 cm × 30 cm was recorded higher plant growth attributes, growth indices, number of filled grains per capitulum, seed index, harvest index and oil per cent. Early initiation of 50% flowering and days to maturity were recorded in planting geometry 75 cm × 30 cm. Whereas, planting geometry 45 cm × 30 cm was found higher grain and stalk yield, number of chaffy grains per capitulum among all the treatments. Application of 80 kg N ha^{-1} was recorded higher plant growth attributes, growth indices, number of filled grains per capitulum, seed index, grain and stalk yield, and harvest index than the 60 kg N ha^{-1}. Early initiation of 50% flowering and days to maturity were recorded in nitrogen level 60 kg ha^{-1}. Application of 25 kg S ha^{-1} recorded higher dry matter accumulation, CGR, number of filled grains per capitulum, grain yield, oil per cent whereas, sulphur level 15 kg ha^{-1} observed highest number of chaffy grains per capitulum.

***Key words*: Sunflower, planting geometry, nitrogen level, sulphur level**

Introduction

Sunflower (*Helianthus annuus* L.) is a member of the asteraceae family. There are 65 different species in the genus *Helianthus* (Andrew *et al*., 2013). The name *Helianthus*, derived from *helios* (the sun) and *anthos* (a flower), has the same meaning as the english name sunflower, which was given to these flowers based on the belief that they follow the sun during the day, always turning towards its direct rays. The sunflower that most people refer to is *H. annuus*, an annual sunflower. In general, it is an annual plant with a large inflorescence (flowering head) and its name is derived from the shape and image of the flower, which is frequently used to resemble the sun. The plant has a rough, hairy stem, broad, coarsely toothed, rough leaves and circular flower heads (Khaleghizadeh, 2011). The heads contain many individual flowers that mature into seeds at the base of the receptacle (Seghatoleslami *et al*., 2012).

In world, sunflower grown over an area of 28.24 million hectares, production 53.03 million metric tons of seed with a productivity of 1.88 metric tons per hectare during 2022-23 (Anonymous, 2023 b). In India, during 2021-22 sunflower grown over an area of 0.28 million hectares with the production of 0.25 million tons of seed and productivity 9.05 q ha^{-1} (Anonymous, 2023a). Sunflower seeds are used as food and dried stalks as fuel. It is the world's fourth largest oil-seed crop. It was already used as an ornamental plant and in ancient ceremonies (Harter *et al*., 2004; Muller *et al*., 2011).

Plants with a greater plant density produce lighter seeds and produce higher yield than low plant density (Beg *et al*., 2007; Ullasa *et al*., 2014). The suitable nitrogen application enhances seed production, seed quality, farm profit, harvest index and reduces nitrogen leaching beyond the crop root zone (Shapiro and Wortmann, 2006; Anwar-ul-Haq *et al*., 2006). The degree of sulphur treatment enhanced grain yield (Bonari *et al*., 2013). Higher levels of sulphur treatment have an influence on grain production (Barbara *et al*., 2008).

Materials and Method

A field experiment was conducted at Shaheed Gundadhoor College of Agriculture and Research Station, Jagdalpur, IGKV, Raipur (C.G.), during *Rabi* season 2022-23, with a split plot design as an experimental framework. The treatments included three different planting geometry such as G1 (45 cm × 30 cm), G2 (60 cm × 30 cm) and G3 (75 cm × 30 cm) in main plot, two nitrogen levels *i.e.* N1 (60 kg ha^{-1}) and N2 (80 kg ha^{-1}) as sub plot and three sulphur levels, such as S1 (15 kg ha^{-1}), S2 (20 kg ha^{-1}) and S3 (25 kg ha^{-1}) in sub plot.

Observations Recorded:

Plant height (cm)

The plant height was measured using a linear meter scale from base of the plant to the apex of the terminal bud / head of the tagged plants at 30 days interval and expressed in cm.

Stem girth (cm)

The diameter at base (above 1st inter node) of the stem of the tagged plants was measured at 30 days interval and at harvest by using vernier callipers and this diameter was later placed in circle perimeter formula for getting stem girth and expressed in centimeters.

Dry matter accumulation (g plant^{-1})

Five plants from each plot were uprooted, shade dried and later oven dried at 65°C for 24 h and the final dry weights were recorded. The average dry matter production plant^{-1} was worked out.

Days to 50% flowering

The number of days required for 50 per cent of the plants to flower was recorded by visual observation in each treatment.

Head diameter (cm) at maturity : Diameter of the heads from the five labelled plants was measured with the help of meter tape and the reading was noted. The average diameter was worked out and expressed in centimeters.

Days to maturity

The number of days required for a crop to reach maturity was recorded by visual observation in each treatment.

Leaf Area Index (LAI)

LAI is the ratio between total leaf areas to ground area. It was calculated by dividing the leaf area per plant by the land area occupied by a single plant (Watson, 1947).

$$\text{Leaf Area Index} = \frac{\text{Total leaf area (cm}^2\text{) plant}^{-1}}{\text{Unit land area occupied by crop (cm}^2\text{)}}$$

Growth analysis

Crop growth characters like Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) were calculated at 30, 60 and 90 DAS based on dry weights and leaf area values.

Number of grains capitulum^{-1}

Number of grains from each of the five flower heads were counted and the average grains head^{-1} was recorded.

Seed Index (g)

One hundred seeds were drawn at random from each treatment and their weights were recorded.

Grain yield (q ha^{-1})

The harvest was threshed separately for each net plot area. To calculate the grain yield per plot, which was then converted to the grain yield per hectare, the grains were winnowed, weighed and recorded. After that, the weight of these grains was measured using an electronic balance.

Stalk yield (q ha^{-1})

The straw, which was a by-product after removing the seeds from the harvested plants, was also weighed and recorded individually for each treatment. It was changed to straw yield ha^{-1}.

Harvest index (%)

Harvest index (HI) is the ratio of economic yield to biological yield. Donald (1962) was given the formula of harvest index equation.

$$\text{HI (\%)} = \frac{\text{Economic yield (Seed yield in kg ha}^{-1}\text{)}}{\text{Biological yield (Seed yield + stalk yield in kg ha}^{-1}\text{)}} \times 100$$

Oil content (%) : Soxhlet apparatus was used for Oil content estimation in seed by using soxhlet extraction method and oil content in seed was calculated with the formula as given below.

$$\text{Oil content (\%)} = \frac{\text{Weight of oil (g)}}{\text{Weight of seed sample (g)}} \times 100$$

Table 1: Effect of different planting geometry, nitrogen and sulphur levels on plant height of sunflower.

Treatments	Plant height (cm)		
	At 30 DAS	At 60 DAS	At harvest
Planting geometry			
G1 45 cm × 30 cm	29.29	147.50	158.27
G2 60 cm × 30 cm	30.22	157.64	169.64
G3 75 cm × 30 cm	32.27	170.05	180.86
SEm±	0.77	3.07	2.63
CD at 5%	NS	11.99	10.26
CV%	10.73	8.22	6.57
Nitrogen levels			
N1 60 kg ha^{-1}	29.73	154.55	166.18
N2 80 kg ha^{-1}	31.45	162.25	173.01
SEm±	0.66	1.61	1.65
CD at 5%	NS	5.54	5.71
CV%	11.18	5.27	5.07
Sulphur levels			
S1 15 kg ha^{-1}	30.61	157.16	168.29
S2 20 kg ha^{-1}	30.36	158.29	169.54
S3 25 kg ha^{-1}	30.81	159.76	170.95
SEm±	0.38	2.16	2.19
CD at 5%	NS	NS	NS
CV%	5.29	5.79	5.47

Interactions were found non significant due to different treatments at all the growth stages; *NS – Non significant

Table 2: Effect of different planting geometry, nitrogen and sulphur levels on stem girth of sunflower.

Treatments	Stem girth (cm)		
	At 30 DAS	At 60 DAS	At harvest
Planting geometry			
G1 45 cm × 30 cm	2.15	5.19	5.24
G2 60 cm × 30 cm	2.15	5.78	6.15
G3 75 cm × 30 cm	2.18	6.30	6.72
SEm±	0.06	0.13	0.16
CD at 5%	NS	0.52	0.63
CV%	11.43	9.80	11.26
Nitrogen levels			
N1 60 kg ha^{-1}	2.12	5.52	5.74
N2 80 kg ha^{-1}	2.20	5.99	6.32
SEm±	0.03	0.11	0.13
CD at 5%	NS	0.38	0.44
CV%	7.60	9.86	10.94
Sulphur levels			
S1 15 kg ha^{-1}	2.14	5.65	5.95
S2 20 kg ha^{-1}	2.16	5.74	6.00
S3 25 kg ha^{-1}	2.18	5.87	6.15
SEm±	0.03	0.10	0.10
CD at 5%	NS	NS	NS
CV%	6.21	7.35	6.87

Interactions were found non significant due to different treatments at all the growth stages; *NS – Non significant

Results and Discussion

Plant height (cm)

Plant height was significantly affected due to different treatments are showed in Table 1. The data reveals that among the planting geometry, treatment G3 (75 cm × 30 cm) produced significantly tallest plant and the smallest plant was found by treatment G1 (45 cm × 30 cm) at 60 DAS and at harvest but it had found non significant effect at 30 DAS due to different planting geometry. Higher plant height at higher planting geometry may result from improved nutrient, light and moisture uptake by the plants. Similar finding was reported by Poonia (2000) and Patel and Thakur (2003). In case of nitrogen levels, treatment N2 (80 kg ha^{-1}) observed significantly taller plant than treatment N1 (60 kg ha^{-1}) at all growth stages except 30 DAS. Increases in nitrogen levels are likely responsible for increased plant height because they promote cell elongation, which may lead to internodal elongation. Similar result was found by Rasool *et al.,* (2015) and Chantal *et al.,* (2018). As regards sulphur levels, treatments found non significant effect at all growth stages due to different sulphur levels and interactions were found non significant due to different treatments at all the growth stages.

Stem girth (cm)

Stem girth was significantly affected due to different treatments are presented in Table 2. The data reveals that among the planting geometry, treatment G3 (75 cm × 30 cm) found significantly highest stem girth which was similar to treatment G2 (60 cm × 30 cm) and the lowest stem girth was found by treatment G1 (45 cm × 30 cm) at 60 DAS and at harvest but it had found non significant effect at 30 DAS. Higher stem girth in higher planting geometry due to better utilization of nutrients, light and moisture. A Similar finding was recorded by Ibrahim *et al.,* (2018). In nitrogen levels, treatment N2 (80 kg ha^{-1}) observed significantly higher stem girth than treatment N1 (60 kg ha^{-1}) at all growth stages except 30 DAS. Maximum stem girth may be attributed to appropriate nutrient availability, which led in increased plant height, higher photosynthate production and higher dry matter production in stem. A Similar result was recorded by Osman and Awed (2010) and Chantal *et al.,* (2018). As regards sulphur levels, treatments recorded non significant effects at all growth stages due to different sulphur levels. At all growth stages, interactions were found non significant due to different treatments.

Table 3: Effect of different planting geometry, nitrogen and sulphur levels on dry matter accumulation of sunflower.

Treatments	Dry matter accumulation (g plant^{-1})		
	At 30 DAS	At 60 DAS	At harvest
Planting geometry			
G1 45 cm × 30 cm	3.41	33.56	98.61
G2 60 cm × 30 cm	3.53	43.06	123.11
G3 75 cm × 30 cm	3.71	48.44	134.83
SEm±	0.07	1.18	2.11
CD at 5%	NS	4.62	8.23
CV%	8.64	12.04	7.52
Nitrogen levels			
N1 60 kg ha^{-1}	3.45	38.30	112.69
N2 80 kg ha^{-1}	3.65	45.07	125.01
SEm±	0.08	0.62	1.54
CD at 5%	NS	2.15	5.32
CV%	11.09	7.75	6.73
Sulphur levels			
S1 15 kg ha^{-1}	3.49	40.44	115.26
S2 20 kg ha^{-1}	3.55	41.67	118.35
S3 25 kg ha^{-1}	3.61	42.94	122.94
SEm±	0.06	0.53	1.68
CD at 5%	NS	1.54	4.89
CV%	7.13	5.36	5.98

Interactions were found non significant due to different treatments at all the growth stages; *NS – Non significant

Table 4: Effect of different planting geometry, nitrogen and sulphur levels on days to 50% flowering and days to maturity of sunflower.

Treatments	Days to 50% flowering	Days to maturity
Planting geometry		
G1 45 cm × 30 cm	66.78	101.06
G2 60 cm × 30 cm	65.61	99.50
G3 75 cm × 30 cm	64.39	97.56
SEm±	0.44	0.64
CD at 5%	1.71	2.51
CV%	2.83	2.74
Nitrogen levels		
N1 60 kg ha^{-1}	65.04	98.89
N2 80 kg ha^{-1}	66.15	99.85
SEm±	0.22	0.20
CD at 5%	0.75	0.70
CV%	1.71	1.06
Sulphur levels		
S1 15 kg ha^{-1}	65.22	99.56
S2 20 kg ha^{-1}	65.61	99.28
S3 25 kg ha^{-1}	65.94	99.28
SEm±	0.28	0.21
CD at 5%	NS	NS
CV%	1.79	0.90

Interactions were found non significant due to different treatments at all the growth stages; *NS – Non significant

Dry matter accumulation (g plant^{-1})

Dry matter accumulation was significantly affected due to different treatments are presented in Table 3. The data represent that among the planting geometry, treatment G3 (75 cm × 30 cm) produced significantly highest dry matter accumulation followed by treatment G2 (60 cm × 30 cm) and lowest dry matter accumulation was found by treatment G1 (45 cm × 30 cm) at 60 DAS and at harvest but it had observed non significant effect at 30 DAS. Due to better utilization of nutrients, light and moisture produced higher dry matter accumulation in higher planting geometry. Similar finding was reported by Poonia (2000). In nitrogen levels, treatment N2 (80 kg ha^{-1}) recorded significantly higher dry matter accumulation than treatment N1 (60 kg ha^{-1}) at all growth stages except 30 DAS. Nasim *et al.,* (2012) observed increase in dry matter accumulation with increasing nitrogen rate was caused by improved crop growth rate, which in turn produced maximum photosynthates and a greater biological yield. Similar result was recorded by Ali *et al.,* (2014). Whereas, in different sulphur levels, treatment S3 (25 kg ha^{-1}) recorded significantly maximum dry matter accumulation which was on par with treatment S2 (20 kg ha^{-1}) and minimum dry matter accumulation was found by treatment S1 (15 kg ha^{-1}) at 60 DAS and at harvest but it was found non significant effect at 30 DAS due to different sulphur levels. Higher dry matter accumulation in plant with higher sulphur level might be due to better cell multiplication and elongation under adequate availability of nutrients as evident from the improved plant growth. Interactions were found non significant due to different treatments at all the growth stages.

Days to 50% flowering and days to maturity

The data recorded for days to 50% flowering and days to maturity are presented in Table 4. The data shows that among the planting geometry, treatment G1 (45 cm × 30 cm) recorded significantly more number of days to 50% flowering and days to maturity, which were on par with treatment G2 (60 cm × 30 cm) and early days to 50% flowering and days to maturity were found by treatment G3 (75 cm × 30 cm). Dhakar *et al.,* (2022) observed lower number of days to 50% flowering was found at 45 cm row spacing as compared to 15 and 30 cm row spacing. Reduced number of days for flowering might be due to the lesser inter row competition for light, nutrient and moisture and have adequate space to extend

Table 5: Effect of different planting geometry, nitrogen and sulphur levels on LAI of sunflower.

Treatments	LAI		
	At 0-30 DAS	At 30-60 DAS	At 60 DAS At harvest
Planting geometry			
G1 45 cm × 30 cm	0.36	2.82	2.31
G2 60 cm × 30 cm	0.30	2.43	1.92
G3 75 cm × 30 cm	0.27	2.27	1.78
SEm±	0.01	0.08	0.07
CD at 5%	0.04	0.29	0.26
CV%	14.56	12.74	13.84
Nitrogen levels			
N1 60 kg ha^{-1}	0.29	2.40	1.90
N2 80 kg ha^{-1}	0.32	2.61	2.11
SEm±	0.01	0.05	0.05
CD at 5%	0.02	0.16	0.17
CV%	10.30	9.85	12.91
Sulphur levels			
S1 15 kg ha^{-1}	0.30	2.45	1.96
S2 20 kg ha^{-1}	0.31	2.51	2.00
S3 25 kg ha^{-1}	0.32	2.56	2.06
SEm±	0.01	0.08	0.07
CD at 5%	NS	NS	NS
CV%	10.30	13.11	14.79
Interactions were found non significant due to different treatments at all the growth stages; *NS – Non significant			

its leaf to intercept more light with less competition. Similar finding for days to 50% flowering was observed by Ali *et al.*, (2014). In case of nitrogen levels, treatment N2 (80 kg ha^{-1}) observed significantly maximum number of days to 50% flowering and days to maturity followed by treatment N1 (60 kg ha^{-1}). Increase in number of days to 50% flowering could be due to increased vegetative growth because of higher nitrogen application. Similar result for days to 50% flowering was reported by Ali *et al.*, (2014). As regards sulphur levels, all treatments were recorded significantly similar result due to different sulphur levels. Interactions were found non significant due to different treatments in both days to 50% flowering and days to maturity..

Leaf area index (LAI)

Data pertaining to Table 5 revealed that the leaf area index shows significant differences due to different treatments. In case of planting geometry, treatment G1 (45 cm × 30 cm) recorded significantly highest LAI value followed by treatment G2 (60 cm × 30 cm) and lowest LAI value found by treatment G3 (75 cm × 30 cm) at 0 – 30 DAS, 30 – 60 DAS and 60 DAS – at harvest. This might be due to increasing plant population was produced more number of leaves thus it had produced more leaf area than the higher planting geometry. Ishfaq *et al.*, (2009) reported that less ground area per plant with higher plant population in dense plant spacing caused more LAI in sunflower. Similar result was found by Rasool *et al.*, (2015) and Ibrahim *et al.*, (2018). Significant differences were observed by various nitrogen levels on LAI and it was found highest by treatment N2 (80 kg ha^{-1}) followed by treatment N1 (60 kg ha^{-1}) at all growth stages. Maximum LAI values were observed under higher nitrogen level can be due to optimum supply of nitrogen that produced broad leaves and more number of leaves per plant that has resulted enhanced photosynthetic surface area. Similar finding were reported by Nasim *et al.*, (2012) and Ali *et al.*, (2014). As regards sulphur levels, all treatments showed non significant effect at 0 – 30 DAS, 30 – 60 DAS and 60 DAS – at harvest. At 0 – 30 DAS, 30 – 60 DAS and 60 DAS – at harvest interactions were found non significant due to different treatments.

Table 6: Effect of different planting geometry, nitrogen and sulphur levels on CGR of sunflower.

Treatments	CGR (g plant^{-1} day^{-1})		
	At 0-30 DAS	At 30-60 DAS	At 60 DAS At harvest
Planting geometry			
G1 45 cm × 30 cm	0.114	1.005	2.169
G2 60 cm × 30 cm	0.118	1.318	2.669
G3 75 cm × 30 cm	0.124	1.491	2.880
SEm±	0.002	0.038	0.052
CD at 5%	NS	0.147	0.201
Nitrogen levels			
N1 60 kg ha^{-1}	0.115	1.162	2.480
N2 80 kg ha^{-1}	0.122	1.381	2.665
SEm±	0.002	0.021	0.058
CD at 5%	NS	0.072	NS
Sulphur levels			
S1 15 kg ha^{-1}	0.116	1.232	2.494
S2 20 kg ha^{-1}	0.118	1.270	2.556
S3 25 kg ha^{-1}	0.120	1.311	2.667
SEm±	0.002	0.018	0.058
CD at 5%	NS	0.054	NS
Interactions were found non significant due to different treatments at all the growth stages; *NS – Non significant			

Crop growth rate (CGR) (g plant^{-1} day^{-1})

Data pertaining to CGR is presented in Table 6. The data reveals that in planting geometry, treatment G3 (75 cm × 30 cm) recorded significantly highest CGR value followed by treatment G2 (60 cm × 30 cm) and lowest CGR value found by treatment G1 (45 cm × 30 cm) at 30 – 60 DAS and 60 DAS – at harvest. Due to better utilization of nutrients, light and moisture produced higher

Table 7: Effect of different planting geometry, nitrogen and sulphur levels on RGR of sunflower.

Treatments	RGR (g g^{-1} plant^{-1} day^{-1})		
	At 0-30 DAS	At 30-60 DAS	At 60 DAS At harvest
Planting geometry			
G1 45 cm × 30 cm	0.0177	0.0330	0.0157
G2 60 cm × 30 cm	0.0182	0.0362	0.0152
G3 75 cm × 30 cm	0.0189	0.0372	0.0149
SEm±	0.0000	0.0000	0.0000
CD at 5%	NS	0.0010	NS
Nitrogen levels			
N1 60 kg ha^{-1}	0.0179	0.0347	0.0157
N2 80 kg ha^{-1}	0.0187	0.0363	0.0148
SEm±	0.0000	0.0000	0.0000
CD at 5%	NS	0.0010	NS
Sulphur levels			
S1 15 kg ha^{-1}	0.0180	0.0353	0.0152
S2 20 kg ha^{-1}	0.0183	0.0354	0.0152
S3 25 kg ha^{-1}	0.0185	0.0357	0.0153
SEm±	0.0000	0.0000	0.0000
CD at 5%	NS	NS	NS

Interactions were found non significant due to different treatments at all the growth stages; *NS – Non significant

Table 8: Effect of different planting geometry, nitrogen and sulphur levels on NAR of sunflower.

Treatments	NAR (g plant^{-1} day^{-1})		
	At 0-30 DAS	At 30-60 DAS	At 60 DAS At harvest
Planting geometry			
G1 45 cm × 30 cm	0.0023	0.0080	0.0101
G2 60 cm × 30 cm	0.0022	0.0096	0.0112
G3 75 cm × 30 cm	0.0021	0.0097	0.0107
SEm±	0.0000	0.0000	0.0000
CD at 5%	NS	0.0010	NS
Nitrogen levels			
N1 60 kg ha^{-1}	0.0022	0.0087	0.0108
N2 80 kg ha^{-1}	0.0022	0.0095	0.0106
SEm±	0.0000	0.0000	0.0000
CD at 5%	NS	0.0010	NS
Sulphur levels			
S1 15 kg ha^{-1}	0.0022	0.0089	0.0104
S2 20 kg ha^{-1}	0.0022	0.0090	0.0106
S3 25 kg ha^{-1}	0.0022	0.0094	0.0110
SEm±	0.0000	0.0000	0.0000
CD at 5%	NS	NS	NS

Interactions were found non significant due to different treatments at all the growth stages; *NS – Non significant

dry matter accumulation in higher planting geometry which reported greater CGR (g plant^{-1} day^{-1}). Significant differences were observed by various nitrogen levels on CGR and it was found highest in treatment N2 (80 kg ha^{-1}) followed by treatment N1 (60 kg ha^{-1}) at 30 – 60 DAS. Increases in dry matter accumulation with nitrogen uptake were caused by higher crop growth rates, which enhanced photosynthates and increased biological yield, which produced greater CGR (g plant^{-1} day^{-1}). Similar result was reported by Rasool *et al.*, (2015). As regards sulphur levels, treatment S3 (25 kg ha^{-1}) observed significantly highest CGR followed by treatment S2 (20 kg ha^{-1}) and lowest CGR recorded by treatment S1 (15 kg ha^{-1}) at 30 – 60 DAS. Higher dry matter accumulation in plant with higher sulphur level might be due to better cell multiplication and elongation under adequate availability of nutrients as evident from the improved plant growth which reported higher CGR (g plant^{-1} day^{-1}). Interactions were found non significant due to different treatments at all the observations.

Relative growth rate (RGR) (g g^{-1} plant^{-1} day^{-1})

RGR was significantly affected by different planting geometry, nitrogen and sulphur levels are presented in Table 7. The data shows that among the planting geometry, treatment G3 (75 cm × 30 cm) was observed significantly higher RGR which had found similar to the treatment G2 (60 cm × 30 cm) and lowest RGR was recorded by treatment G1 (45 cm × 30 cm) at 30 – 60 DAS whereas, at 0-30 DAS and 60 DAS-at harvest it was found non significant. Due to better utilization of nutrients, light and moisture produced higher dry matter accumulation in higher planting geometry which reported greater RGR (g g^{-1} plant^{-1} day^{-1}). While Significant differences were observed by various nitrogen levels on RGR and it was observed highest in treatment N2 (80 kg ha^{-1}) followed by treatment N1 (60 kg ha^{-1}) at 30 – 60 DAS. Increases in accumulation of dry matter with increase in nitrogen uptake were caused by higher crop growth rates, which enhanced photosynthates and increased biological yield, which produced greater RGR (g g^{-1} plant^{-1} day^{-1}). As regards sulphur levels, all treatments were recorded non significant effect at 0 – 30 DAS, 30 – 60 DAS and 60 DAS – at harvest due to different sulphur levels. Interactions were found non significant due to different treatments at all the growth stages.

Net assimilation rate (NAR) (g plant^{-1} day^{-1})

Table 8 shows significant differences due to different planting geometry, nitrogen and sulphur levels on NAR. The data reveals that among the planting geometry, treatment G3 (75 cm × 30 cm) recorded significantly highest NAR which was on par with treatment G2 (60 cm × 30 cm) and lowest NAR was recorded in treatment G1 (45 cm × 30 cm) at 30 – 60 DAS. Due to better utilization of nutrients, light and moisture produced higher

Table 9: Effect of different planting geometry, nitrogen and sulphur levels on seed index and oil per cent of sunflower.

Treatments	Head diameter (cm) at maturity	No. of filled grains capitulum^{-1}	No. of chaffy grains capitulum^{-1}	Seed index (g)	Oil (%)	Grain yield (q ha^{-1})	Stalk yield (q ha^{-1})	HI (%)
Planting geometry								
G1 45 cm × 30 cm	13.87	564.65	106.33	6.33	27.70	20.24	36.40	35.68
G2 60 cm × 30 cm	15.12	685.91	91.91	6.67	31.68	19.19	31.93	37.54
G3 75 cm × 30 cm	16.39	786.35	84.63	6.93	34.68	17.27	26.07	39.72
SEm±	0.30	13.00	1.75	0.10	0.17	0.36	1.05	0.60
CD at 5%	1.19	50.76	6.82	0.40	0.67	1.42	4.09	2.34
CV%	8.51	8.12	7.86	6.49	2.31	8.14	14.11	6.75
Nitrogen levels								
N1 60 kg ha^{-1}	14.53	635.21	104.14	6.50	32.52	17.15	29.57	36.87
N2 80 kg ha^{-1}	15.72	722.73	84.44	6.78	30.18	20.65	33.56	38.42
SEm±	0.24	10.04	1.91	0.07	0.11	0.31	0.42	0.37
CD at 5%	0.84	34.64	6.59	0.23	0.37	1.06	1.44	1.27
CV%	8.32	7.68	10.52	5.11	1.76	8.44	6.87	5.06
Sulphur levels								
S1 15 kg ha^{-1}	14.80	644.20	102.81	6.52	30.04	18.11	30.72	37.12
S2 20 kg ha^{-1}	15.13	685.74	93.11	6.61	31.68	18.96	31.77	37.80
S3 25 kg ha^{-1}	15.45	706.96	86.94	6.80	32.33	19.63	32.74	38.02
SEm±	0.23	15.58	2.70	0.08	0.16	0.41	0.54	0.65
CD at 5%	NS	45.49	7.89	NS	0.47	1.19	NS	NS
CV%	6.49	9.74	12.16	5.17	2.18	9.12	7.25	7.29

Interactions were found non significant due to different treatments at all the growth stages; *NS – Non significant

dry matter accumulation in higher planting geometry which reported greater NAR (g plant^{-1} day^{-1}). Significant differences were observed by various nitrogen levels on NAR and it was found highest by treatment N2 (80 kg ha^{-1}) which had found similar result with treatment N1 (60 kg ha^{-1}) at 30 – 60 DAS. Increases in dry matter accumulation with nitrogen uptake were caused by higher crop growth rates, which enhanced photosynthates and increased biological yield, which produced greater NAR (g plant^{-1} day^{-1}). As regards sulphur levels, all treatments were recorded non significant effect at 0 – 30 DAS, 30 – 60 DAS and 60 DAS – at harvest. At all the growth stages interactions were found non significant due to different treatments.

Head diameter (cm) at maturity

Head diameter was significantly affected due to different treatments are presented in Table 9. The data reveals that in planting geometry, treatment G3 (75 cm × 30 cm) observed significantly maximum head diameter followed by treatment G2 (60 cm × 30 cm) and treatment G1 (45 cm × 30 cm) was recorded smaller head diameter at the maturity stage. The possible reason for maximum head diameter was due to proper utilization of nutrients, light, moisture and less plant competition in higher planting geometry. Similar finding was reported by Ahmad and Quresh (2000), Poonia (2000) and Rasool *et al.*, (2015). Nitrogen levels show treatment N2 (80 kg ha^{-1}) observed significantly higher head diameter than treatment N1 (60 kg ha^{-1}) at the maturity stage. Generally, larger heads harvested with miximum nitrogen application and were related with higher number of grains which produced more yields. Similar result was observed by Rasool *et al.* (2015) and Chantal *et al.*, (2018). As regards sulphur levels, all treatments were recorded non significant effect due to different sulphur levels. Interactions were found non significant due to different treatments.

No. of filled and chaffy grains capitulum^{-1}

The data recorded for number of filled and chaffy grains per capitulum is presented in Table 9.

No. of filled grains capitulum^{-1}

The data shows that among the different planting geometry, treatment G3 (75 cm × 30 cm) recorded significantly highest number of filled grains per capitulum followed by treatment G2 (60 cm × 30 cm) and the least number of filled grains per capitulum were found by treatment G1 (45 cm × 30 cm). Due to better utilization of nutrients, light and moisture produced higher number of filled grains per capitulum in higher planting geometry. Whereas, in nitrogen levels, treatment N2 (80 kg ha^{-1}) observed significantly more number of filled grains per capitulum followed by treatment N1 (60 kg ha^{-1}). Maximum number of filled grains per capitulum was due to the adequate supply of nutrients. As regards to sulphur levels, treatment S3 (25 kg ha^{-1}) recorded significantly higher number of filled grains per capitulum which had found similar with treatment S2 (20 kg ha^{-1}) and least number of filled grains per capitulum observed by treatment S1 (15 kg ha^{-1}). Maximum number of filled grains per capitulum with higher sulphur level might be due adequate availability of nutrients as evident from the improved plant growth. Interactions were found non significant due to different treatments.

No. of chaffy grains capitulum^{-1}

Among the planting geometry, treatment G1 (45 cm × 30 cm) recorded significantly highest number of chaffy grains per capitulum followed by treatment G2 (60 cm × 30 cm) and the lowest number of chaffy grains per capitulum was found by treatment G3 (75 cm × 30 cm). Due to better utilization of nutrients, light and moisture produced lower number of chaffy grains per capitulum in higher planting geometry. In case of nitrogen levels, treatment N1 (60 kg ha^{-1}) observed significantly greater number of chaffy grains per capitulum. Minimum number of chaffy grains per capitulum was due to the adequate supply of nutrients. As regards to sulphur levels, treatment S1 (15 kg ha^{-1}) found significantly highest number of chaffy grains per capitulum followed by treatment S2 (20 kg ha^{-1}) whereas, treatment S3 (25 kg ha^{-1}) reported lowest number of chaffy grains per capitulum. Minimum number of chaffy grains per capitulum with higher sulphur level might be due adequate availability of nutrients as evident from the improved plant growth. Interactions were found non significant due to different treatments.

Grains yield (q ha^{-1}), stalk yield (q ha^{-1}) and harvest index (%) of sunflower

Table 9 shows significant differences in grain yield stalk yield and harvest index (HI). The data reveals that treatment G1 (45 cm × 30 cm) produced significantly highest grain and stalk yield among all the planting geometry but treatment G2 (60 cm × 30 cm) was found statistically on par with treatment G1 (45 cm × 30 cm) in grain yield, while harvest index (HI) was recorded significantly higher in treatment G3 (75 cm × 30 cm) which was similar with treatment G2 (60 cm × 30 cm). The reason for more grain and stalk yield of sunflower might be due to more number of plants per hectare produced more number of effective capitulum which increased yield. Similar finding for grain yield was recorded by Paraye and Chaubey (2010), Ali *et al.*, (2014) and Rasool *et al.*, (2015) while Legha and Giri (1999) and Sen *et al.*, (2002)\ recorded similar result for stalk yield. As regards to harvest index (HI) similar finding was recorded by Sneha *et al.*, (2022). As regards to nitrogen levels, treatment N2 (80 kg ha^{-1}) produced significantly higher grain and stalk yield, and harvest index (HI) than the treatment N1 (60 kg ha^{-1}). Higher growth characteristics, a larger head diameter, and more filled grains per capitulum were all positively correlated with increased grain and stalk yield due to an appropriate supply of nitrogen. The most significant contributing factor that increases seed yield is head diameter, which produces the highest number of flowers required for higher seed set. The yield of seeds and stalks was affected by the combined effects of all these growth and yield components, and the impact of a sufficient N supply was clearly visible. Similar result for grain yield was observed by Gul and Kara (2015) and May *et al.*, (2018) whereas, Reddi and Reddy (2003) and Pavani *et al.*, (2013) recorded similar finding for straw yield. Similar result for harvest index (HI) was found by Gul and Kara (2015) and Rasool *et al.*, (2015). In case of sulphur levels, treatment S3 (25 kg ha^{-1}) was recorded significantly higher grain yield which had observed on par with treatment S2 (20 kg ha^{-1}). Higher seed yield under higher sulphur application was caused by healthy growth, and sufficient sulphur availability may have increased the accumulation of amide and amino acid substances. These substances translocation to the reproductive organs increased seed filling and setting, which in turn increased seed yield. Stalk yield and harvest index (HI) were observed non significant effect due to different sulphur levels. Similar result for grain yield was showed by Biswas and Poddar (2015), Abhilash *et al.*, (2019) and Saleem *et al.*, (2019). Interactions were found non significant due to different planting geometry, nitrogen and sulphur levels.

Seed index (g) and oil per cent

The data recorded on seed index and oil per cent is presented in Table 9. The table shows that treatment G3 (75 cm × 30 cm) recorded significantly higher seed index and oil per cent but seed index was found similar with treatment G2 (60 cm × 30 cm) in seed index. The reason of more seed index and oil per cent at higher planting geometry might be due to better utilization of nutrients, light and moisture among plants. Similar result for oil per cent was showed by Kazemeini *et al.*, (2009). In nitrogen levels, treatment N2 (80 kg ha^{-1}) observed maximum seed index than the treatment N1 (60 kg ha^{-1}) whereas, treatment N1 (60 kg ha^{-1}) produced higher per cent of oil than the treatment N2 (80 kg ha^{-1}). Due to optimum supply of nitrogen level resulted in over production of protein, causing a reduction in oil content. Gul and Kara (2015) and Rasool *et al.*, (2015) were found similar result for oil per cent. As regards to sulphur levels, treatment S3 (25 kg ha^{-1}) was found higher oil per cent than the treatment S2 (20 kg ha^{-1}) and S1 (15 kg ha^{-1}) while, seed index was not found significant due to different sulphur levels. Higher oil per cent at higher sulphur level is due to adequate supply accelerate the metabolic pathway produced greater unsaturated fatty acid such as linoleic and linolenic acid. Similar finding for oil per cent was reported by Abhilash *et al.*, (2019) and Saleem *et al.*, (2019). Interactions were found non significant due to different treatments.

Conclusion

Among the planting geometry, 75 cm × 30 cm was recorded higher plant growth attributes and growth indices. Early initiation of 50% flowering and days to maturity were recorded in higher planting geometry 75 cm × 30 cm. As regards to nitrogen level, 80 kg ha^{-1} was recorded higher plant growth attributes and growth indices while early initiation of 50% flowering and days to maturity were recorded at nitrogen level, 60 kg ha^{-1}. In case of sulphur level, 25 kg ha^{-1} observed highest dry matter accumulation and CGR. Among the planting geometry, 45 cm × 30 cm was found higher grain and stalk yield, and number of chaffy grains per capitulum while planting geometry, 75 cm × 30 cm reported highest number of filled grains per capitulum, seed index, harvest index and oil per cent. As regards to nitrogen levels, 80 kg ha^{-1} recorded higher number of filled grains per capitulum, seed index, grain and stalk yield, and harvest index. Nitrogen level 60 kg ha^{-1} recorded higher oil per cent and number of chaffy grains per capitulum. Application of 25 kg sulphur per hectare recorded higher number of filled grains per capitulum, grain yield and oil per cent whereas, sulphur level, 15 kg ha^{-1} observed more number of chaffy grains per capitulum.

Key points

1. Among the planting geometry, 45 cm × 30 cm was recorded higher grain and stalk yield.
2. While planting geometry, 75 cm × 30 cm reported highest number of filled grains per capitulum, seed index, harvest index and oil per cent.
3. In nitrogen levels, 80 kg ha^{-1} recorded higher number of filled grains per capitulum, seed index, and grain and stalk yield, and harvest index.
4. Application of 25 kg sulphur per hectare recorded higher number of filled grains per capitulum, grain yield and oil per cent.

Acknowledgement

I would like to take this opportunity to place my profound debt of gratitude on record to my Major Advisor and Chairman of the Advisory Committee, Dr. Ashwani Kumar Thakur, Principal Scientist, Department of Agronomy, S.G. College of Agriculture and Research Station, Jagdalpur (C.G.) for his valuable suggestions, encouragement, affection, personal guidance, keen interest, immeasurable help and inspiration.

Conflict of interest: There is no potential conflict of interest declared by any authors.

References

Abhilash, B.N., Ravi M.V., Naik A. and Latha H.S. (2019). Effect of different sources and levels of sulphur on yield, sulphur uptake and quality of rainfed sunflower (*Helianthus annus* L.). *Journal of Pharmacognosy and Phytochemistry*, **8(5)**, 1385-1388. https://www.phytojournal.com/archives/2019/vol8issue5/PartZ/8-4-800-328.pdf.

Ahmad, G. and Quresh Z. (2000). Plant population of sunflower under different planting dates. *Pakistan Journal of Biological Sciences*, **3(11)**, 1820-1821. https://doi.org/10.3923/pjbs.2000.1820.1821.

Ali, A., Ahmad A., Khaliq T., Afzal M., Iqbal M. and Qamar R. (2014). Plant population and nitrogen effects on achene yield and quality of sunflower (*Helianthus annuus* L.) hybrids. International Conference on Agricultural, Environmental and Biological Sciences, Phuket, Thailand, 24-25. http://dx.doi.org/10.15242/IICBE.C414001

Andrew, R.L., Kane N.C., Baute G.J., Grassa C.J. and Rieseberg L.H. (2013). Recent nonhybrid origin of sunflower ecotypes in a novel habitat. *Mol. Ecol*. **22(3)**, 799-813. http://doi.org/10.1111/mec.12038

Anonymous (2023a). Agricultural Statistics at a Glance 2022. Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India, New Delhi. May, 92. https://desagri.gov.in/wp-content/uploads/2023/05/Agricultural-Statistics-at-a-Glance-2022.pdf.

Anonymous (2023b). World Agricultural Production. USDA, Foreign Agricultural Service, Washington DC. November, 39. https://apps.fas.usda.gov/psdonline/circulars/production.pdf

Anwar-ul-Haq, Rashid A., Butt M.A., Akhter M.A., Aslam M. and Saeed A. (2006). Evaluation of sunflower (*Helianthus annuus* L.) hybrid for yield and yield components in central Punjab. *J. Agric. Res*. **44**, 277-285. https://agris.fao.org/search/en/providers/122650/records/647246dd53aa8c8963048f31#!

Barbara, C.E.H., Hrastar R., Tajnsek A. and Kosir I.J. (2008). Impact of source and application time of sulphur on the yield, oil content and protein content in winter oilseed rape. *Acta. Agric. Sci*. **91(1)**, 208-215. https://doi.org/10.2478/v10014-008-0001-x

Beg, A., Pourdad S.S. and Alipour S. (2007). Row and plant spacing effects on agronomic performance of sunflower in warm and semi-cold area of Iran. *Helia*., **30(47)**, 99-104. https://doi.org/10.2298/hel0747099b

Biswas, B. and Poddar R. (2015). Yield and nutrients uptake of sunflower *(Helianthus annuus)* as influenced by different level of nitrogen and sulphur. *An International Quarterly Journal of Life Sciences*, **10(1)**, 1-6. https://www.academia.edu/download/45286086/Bioscan_Sunflower.pdf

Bonari, A., Mousavi N.M., Behdani M.A. and Besharati H. (2013). Effect of sulphur fertilizer and split nitrogen application on seed yield and its components of sunflower (*Helianthus annuus* L.). *Elec. J. Crop Pro*., **6(3)**, 1-15.

Chantal, K., IroOng'or B.T., Bandhushubwenge D., Soter N. and Felix S. (2018). Effect of different nitrogen fertilizer levels on sunflower growth and yield attributes. *Pak. J. Nutr*. **17**, 557-562. http://doi.org/10.3923/pjn.2018.557.562.

Dhakar, R.L., Patel A.G., Saini Y., Nagar B.L. and Patel D. (2022). Effect of sowing dates and row spacing on forage yield of sunflower (*Helianthus annuus* L.). *The Pharma Innovation Journal*, **11(4)**, 1842-1845. https://www.thepharmajournal.com/archives/2022/vol11issue4/PartZ/11-4-42-784.pdf

Donald (1962). In search of yield. *Journal of Australian Agricultural Science,* **28**, 171- 178.

Gul, V. and Kara K. (2015). Effect of different nitrogen doses on yield and quality traits of common sunflower (*Helianthus annuus* L.). *Turkish Journal of Field Crops*, **20(2)**, 159-165. http://doi.org/10.17557/tjfc.40041

Harter, A.V., Gardner K.A., Falush D., Lentz D.L., Bye R.A. and Rieseberg L.H. (2004). Origin of extant domesticated sunflower in eastern North America. *Nature*, **430(6996)**, 201-205. https://www.academia.edu/download/39359696/Origin_of_extant_domesticated_sunflowers_in_eastern_North_America._Nature20151022-28244-ns0oa1.pdf

Ibrahim, M.O., Mohamad Ahmed B.E.A., Ishag A.A. and Mohammad H.A.I. (2018). Influence of plant spacing and sowing depth on growth and yield of sunflower (*Helianthus annuus* L.) in halfa elgadidah scheme, Sudan. *International J. Sci. and Res*. **7(5)**, 1177-1179. http://doi.org/10.21275/14051801

Ishfaq, M., Ali A., Khaliq A. and Yaseen M. (2009). Allometry, agronomic traits and yield of autumn planted sunflower hybrids under varying row spacing. *Pakistan Journal of Agricultural Sciences*, **46(4)**, 248-257. https://www.pakjas.com.pk/papers/76.pdf

Kazemeini, A.S., Edalat M. and Shekoofa A. (2009). Interaction effects of deficit irrigation and row spacing on sunflower growth, seed yield and oil yield. *African Agri. Res*. **4**, 1165-1170. https://academicjournals.org/journal/AJAR/article-full-text-pdf/467FCFA37782.pdf

Khaleghizadeh, A. (2011). Effect of morphological traits of plant, head and seed of sunflower hybrids on house sparrow damage rate. *Crop Prot*. **30(3)**, 360-367. https://doi.org/10.1016/j.cropro.2010.12.023

Legha, P.K. and Giri G. (1999). Effect of date of sowing and planting geometry on spring sunflower (*Helianthus annuus*). *Indian Journal of Agronomy*, **44(2)**, 404-407. https://agris.fao.org/search/en/providers/122648/records/6472363953aa8c896302580f#!

May, W.E., Dawson M.P. and Lyons C.I. (2018). Response of sunflowers (*Helianthus annuus* L.) to varying seeding rates and nitrogen fertilizer rates in a no-till cropping system in Saskatchewan. *Can. J. Plant Sci*. **98**, 1331-1341. http://dx.doi.org/10.1139/cjps-2017-0313

Muller, M.H., Latreille M. and Tollon C. (2011). The origin and evolution of a recent agricultural weed; population genetic diversity of weedy populations of sunflower (*Helianthus annuus* L.) in Spain and France. *Evol. Appl*. **4(3)**, 499-514. https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1752-4571.2010.00163.x

Nasim, W., Ahmad A., Bano A., Olatinwo R., Usman M., Khaliq T., Wajid A., Hammad H.M., Mubeen M. and Hussain M. (2012). Effect of nitrogen on yield and oil quality of sunflower (*Helianthus annuus* L.) hybrids under sub humid conditions of Pakistan. *American Journal of Plant Sciences*, **3**, 243-251. http://doi.org/10.4236/ajps.2012.32029.

Osman, E.B.A. and Awed M.M.M. (2010). Response of sunflower (*Helianthus annuus* L.) to phosphorus and nitrogen fertilization under different plant spacing at new valley. *Ass. Univ. Bull. Environ. Res*. **13(1)**, 11-19. https://pesquisa.bvsalud.org/portal/resource/pt/emr-97541

Paraye, P.M. and Chaubey A.K. (2010). Effect of nutrient management and plant density on growth, yield attributes and yield of sunflower (*Helianthus annuus*). *Pantnagar Journal of Research*, **8(2)**, 148-150. https://www.cabdirect.org/cabdirect/abstract/20113149555

Patel, S.R. and Thakur D.S. (2003). Effect of crop geometry, phosphorus levels and phosphate solubilizing bacteria on growth, yield and oil content of sunflower, *Helianthus annuus*. *Journal of Oilseeds Research*, **20(1)**, 153-154.

Pavani, S., Rekha B., Sudhakara Babu S.N. and Moguloju M. (2013). Effect of nitrogen and sulphur on growth, yield and quality of sunflower (*Helianthus annuus* L.). *Crop Res*. **45(3)**, 152-154. https://www.indianjournals.com/ijor.aspx?target=ijor:cr1&volume=45&issue=1to3&article=030

Poonia, K.L. (2003). Effect of planting geometry, nitrogen and sulphur on seed quality of sunflower (*Helianthus annuus* L.). *Annal Agricultural Research*, **24(4)**, 828-832.

Rasool, K., Wajid A., Sanaullah, Ghaffar A., Shoaib M., Arshad M. and Abbas S. (2015). Optimizing nitrogen rate and planting density for sunflower under irrigated conditions of Punjab. *SAARC J. Agri*. **13(1)**, 174-187. https://doi.org/10.3329/SJA.V13I1.24190

Reddi, Y.R. and Reddy M.P. (2003). Yield, quality and economics of sunflower as influenced by nitrogen and sulphur nutrition. *Journal of Oilseeds Research*, **20(1)**, 131-132.

Saleem, M.F., Malik M.A. and Wahid M.A. (2008). Yield and quality response of autumn-planted sunflower (*Helianthus annuus* L.) to sowing dates and planting patterns. *Canadian Journal of Plant Science*, **88**, 101-109. https://doi.org/10.4141/CJPS07052

Seghatoleslami, M.J., Bradaran R., Ansarinia E. and Mousavi S.G. (2012). Effect of irrigation and nitrogen level on yield, yield components and some morphological traits of sunflower. *Pak. J. Bot.*, **44(5)**, 1551-1555. https://www.pakbs.org/pjbot/PDFs/44(5)/10.pdf

Sen, A., Singh R., Sharma S.N., Mishra P.J., Singh A.K. and Pal A.K. (2002). Effect of planting density on yield attributes, yield and nutrient uptake of restorer lines of sunflower, *Helianthus annuus* L. hybrid. *Journal of Oilseeds Research*, **19(1)**, 46-49.

Shapiro, C.A. and Wortman C.S. (2006). Corn response to nitrogen rate, row spacing and plant density in Eastern Nebraska. *Agron. J.*, **98**, 529-535. https://doi.org/10.2134/agronj2005.0137

Sneha, M.A., Desai B.K., Umesh M.R., Koppalkar B.G. and Kuchanur P.H. (2022). Effect of planting density and fertilizer rate on performance of newly developed sunflower hybrids (*Helianthus annuus* L.). *The Pharma Innovation Journal*, **11(8)**, 167-178. https://www.thepharmajournal.com/archives/2022/vol11issue8/PartB/11-7-293-101.pdf

Ullasa, M.Y., Sheshadri T., Nagaraj R., Sudheendra S., Basavaraj K. and Bhavya M.R. (2014). Effect of application of farmyard manure, fertilizer levels and different plant population levels on seed yield, nutrient uptake by sunflower and final nutrient status of the soil. *Trends in Biosci*. **7(5)**, 393-395.

Watson, D.J. (1947). Comparative physiological studies on the growth of field crops. Variation in net assimilation rate and leaf area between species and varieties and within and between years. *Annays of Botany*, **11**, 41-76.