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Research Article

INFLUENCE OF INCREASED SOURCE SIZE ON SEED SET AND PRODUCTIVITY IN SUNFLOWER (*Helianthus annuus* L.)

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Abstract- The study was to increase the source size per unit land area by manipulating plant density (spacing) and nutrient level (mainly nitrogen). The crop was grown with different levels of nitrogen (50 %, 100 % and 200 %) in combination with two different spacing (60 x 30cm^2 and 45 x 30cm^2) and growth regulator mixture comprising 20 ppm NAA, 10 ppm GA and 20 ppm BA was imposed. Effect of defoliation in two different spacing was also studied. With wider spacing, number of achenes and 100 achene weight per head were higher due to less plant population that produced significantly bold grains which reduced the competition between the plants and also allowed more light interception and availability of nutrients. Among all the treatments, the plants treated with 200 % N along with growth regulator mixture increased absolute growth rate (AGR), seed yield, total dry matter (TDM) and oil content under both plant densities. This treatment enhanced leaf area duration by 15.7%, seed yield was reduced by 32%, due to lesser number of plants/m^2. There was no significant difference between the seasons and also between different plant densities in seed yield per plant. In the same treatment, similar observations were recorded for TDM through seed yield/m^2 which was more in 60 x 30 cm^2 spacing. Whereas biomass/m^2 was more in 45 x 30 cm^2 spacing up to 30 per cent. Seed yield and TDM were high in *rabi* compared to *kharif*. The overall conclusion from this study is, increasing source size by applying 200% N combined with growth regulator mixture by maintaining recommended plant density and productivity can be increased up to 10-15 per cent.

Keywords- Plant growth hormones, Nitrogen, Plant density, Leaf area duration, Harvest index, Productivity.

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Introduction

Sunflower is a rich source of edible oil. In India sunflower was introduced in early seventies and holds has a potential oil seed crop in the present oil crisis due to its desirable attributes such as early maturity, adaptability to wide range of climate and soil conditions, photo and thermo insensitiveness and drought tolerance. Though the crop having several advantages, due to poor seed setting and large percentage of hallow seeds in its capitulum with poor germination the productivity is becoming low. This problem demands greater attention due to its adverse effect on seed yield and quality of produce.

Several authors reported that the seed yield of sunflower was greatly influenced by plant densities and nitrogen-phosphorus-potassium fertilizers. Of the nutrients required by the plants, nitrogen (N) is the most essential and is required in largest amount. It is vitally an important plant nutrient and the most frequently deficient of all nutrients [1]. Application of nitrogen to crops produces abundant vegetative growth, large leaves with deep green color and good yield.

Plant spacing effects are highly pronounced in crops such as sunflower because there is no possibility of filling gaps between plants by branching and tillering and it is the single most important management factor that determines total amount of intercepted radiation under field conditions thus growth and productivity of crop plants. So, an attempt has been made to study the effect of plant spacing, different nitrogen levels and growth regulators for getting maximum yield of sunflower.

Leaves are vitally essential organs for photosynthesis, which is a major process affecting crop growth rates and is affected either by the number or the area of the leaves. In addition, leaves also play a vital part in controlling water loss by plants. Karadogan and Akgun [2] reported that Sunflower yield, yield components and quality are influenced by the removal of leaves per plant, while the removal in excess of more than 8 leaves does affect yield and quality.

Keeping these aspects in view, the field experiment was conducted to study the influence of increased source size on seed set and productivity in sunflower.

Material and Methods

The field experiment was conducted at AICRP on sunflower, ZARS University of Agricultural Sciences, Bengaluru, situated at 12^0 58^1 north latitude and 77^0 35^1 east longitude at an altitude of 930 meter above mean sea level. The soil is red sandy clay loam with slightly acidic (pH 6.26) and the electrical conductivity was normal (0.12 m mhos/cm at 25 °C).

The experiment was conducted in sunflower hybrid, KBSH-44 and laid out in the randomized complete block design with three replications. Recommended dose of 60:90:60 kg N, P_2O_5, K_2O per ha in the form of Urea, DAP and Muriate of potash was applied to the soil.

In the experiment, sunflower hybrid KBSH-44 was treated with different levels of N (50, 100 and 200 %) keeping P and K constant for manipulating the source size. In addition, sink was also manipulated by applying growth regulator mixture (10 ppm of GA + 20 ppm of BA + 20 ppm NAA) with 200 % N. The other treatments included application of 200 % N with removal of 33 % basal and middle leaves to reduce source size and application of 100 % N as control. All these treatments were imposed at two different plant densities (60 x 30 cm^2 and 45 x 30 cm^2) both in *kharif* 2012 and *rabi* summer 2013 to study the seasonal effects.

The sunflower hybrid KBSH-44 released from UAS, Bangalore, was used for the study. Seeds were obtained from AICRP on sunflower, ZARS, UAS, GKVK, Bengaluru. The crop was harvested at physiological maturity based on visual observation. The harvested plants from each treatment and replication were sun dried separately. The seeds were cleaned and threshed manually by beating with stick.

Ten uniform plants in each treatment selected and tagged randomly 30 days after sowing for recording various morphological characters like plant height, number of leaves, SPAD chlorophyll meter readings, dry matter production and its distribution and physiological parameters like leaf area index (LAI), leaf area duration (days), absolute growth rate (g m^{-2} day^{-1}) and yield and yield components like head diameter (cm), number of seeds per plant, test weight (g/100 seeds), per cent of filled seeds per head, seed yield, harvest index (HI) and oil content (%).

The data was subjected to the analysis of variance following the method of Gomez and Gomez [3]. The level of significance in "F" and "t" tests was P=0.05. Critical differences were calculated whenever "F" test was found significant.

Results and Discussion

Main objective of the experiment was to study the source to sink relationship by varying plant densities (increasing source size) on physiological, morphological and yield parameters in sunflower.

In *kharif,* at 60 DAS, plants treated with 200 % N + Growth regulator mixture (T_4 and T_{10}) sprayed after anthesis showed maximum plant height in both plant densities (187.5 cm and 185.5 cm, respectively). The plant height was less when 50 % N was applied which was significantly lower than the control (T_2 and T_8). Similar trend was observed in *rabi* also.

Application of higher dose of N tended to increase plant height significantly [Table-1] may be due to increased photosynthesis and plant growth [4,5].

Table-1 *Influence of increased source size on morphological parameters duringkharif and rabiin sunflower*

Treatments	Plant height (cm)		Number of leaves		Total leaf area		SPAD readings	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
T_1	182.53	190.15	37.00	36.00	10382.87	9824.15	37.52	37.81
T_2	184.20	193.23	39.30	37.27	11132.46	11012.54	40.34	40.81
T_3	185.40	195.03	39.50	37.40	12697.37	12854.77	40.06	40.34
T_4	187.53	196.91	40.30	37.47	12779.21	13052.11	40.54	41.78
T_5	185.33	195.96	26.10	25.80	8457.09	8306.34	38.46	36.38
T_6	185.07	195.13	25.40	24.60	8321.32	8212.79	39.71	30.67
T_7	180.20	189.20	35.70	32.93	9536.36	9621.61	35.43	38.07
T_8	182.93	192.80	36.40	34.47	10425.35	10663.95	40.92	40.37
T_9	184.07	194.20	36.90	34.67	11825.95	11927.96	39.66	38.88
T_{10}	185.57	195.50	39.70	35.47	12610.67	12987.10	38.70	37.52
T_{11}	184.98	195.10	25.30	34.87	8268.58	8040.39	39.75	35.24
T_{12}	184.03	194.00	24.80	34.20	8246.11	8006.51	39.08	30.01
Mean	**184.11**	**194.28**	**33.01**	**33.19**	**10390.27**	**10375.85**	**39.23**	**36.93**
SEm±	**2.10**	**3.12**	**0.36**	**0.49**	**318.95**	**382.37**	**1.05**	**1.35**
CD @ 5%	**6.15**	**9.71**	**1.13**	**1.44**	**935.46**	**1190.20**	**NS**	**NS**
CV (%)	**1.86**	**2.27**	**1.44**	**2.43**	**4.67**	**5.18**	**4.63**	**4.85**

Leaf area is one of the important traits in increasing productivity of crop plants. In the present study, the leaf area and leaf area index were increased up to 75 DAS and decreased thereafter due to senescence and ageing of leaves. Application of 200% N with growth regulator mixture had a profound effect on increasing leaf area around 12000 cm^2 per plant under both plant densities. The combination of growth regulator mixture containing BA, NAA and GA have the ability to delay senescence of leaf, arresting the chlorophyll degradation and protease activity and promoting the synthesis of soluble protein and enzyme [6]. This may be attributed to the retention of more leaves per plant in growth hormone treatments by delaying senescence of the leaves resulting in retaining higher assimilation surface area for longer period.

Increasing levels of nitrogen during vegetative stage can strengthen and support roots enabling plants to take up more water and nutrients. This allows the plants to grow more rapidly and produce larger leaf area. Wider spacing provided more light interception and increased feeding area for the plants.

Additional growth regulator mixture did not have any significant effect on leaf area enhancement over the 200 % N. Similarly, enhancing the N from 100% to 200 % also did not improve the leaf area significantly. Interestingly, in the treatment, 200% N + growth regulator mixture such as BA showed lesser reduction in green leaf area compared to the other treatments. Possibly the growth regulators delayed senescence. In this regard, Srivastava and Goswami, [6] have shown delayed leaf senescence with application of BA. The results indicate that in addition to increase in LA, maintenance of functional leaf area also enhance the productivity in sunflower.

Table-2 *Influence of increased source size on growth parameters during kharif and rabiin sunflower*

Treatments	Leaf area index (LAI)		Leaf area duration (LAD)		Absolute growth rate (g m^2 day^{-1})	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
T_1	4.45	5.02	46.05	46.23	9.08	11.33
T_2	4.90	5.18	50.80	51.07	9.57	12.16
T_3	5.23	5.44	58.78	59.00	13.20	12.49
T_4	5.38	5.85	59.76	60.23	13.99	12.98
T_5	4.04	4.73	39.62	39.33	10.29	6.88
T_6	4.09	4.67	36.69	38.89	9.52	5.72
T_7	4.49	6.67	57.37	60.13	10.80	15.76
T_8	5.74	6.85	64.99	66.10	12.28	16.28
T_9	6.45	7.20	72.75	73.47	16.30	16.65
T_{10}	8.20	7.69	80.65	79.84	16.38	17.02
T_{11}	6.30	6.25	52.73	52.03	13.10	8.88
T_{12}	6.05	6.10	47.60	51.69	12.58	8.81
Mean	5.78	6.15	57.09	58.07	12.84	12.15
SEm±	0.39	0.33	2.10	2.42	0.14	0.06
CD @ 5%	1.20	1.04	6.54	7.55	0.43	0.20
CV (%)	9.43	8.36	4.68	5.53	2.12	0.98

During our experimental period, bright sunshine hours in *rabi* were higher (8.4) than *kharif* (5.77) and also maximum and minimum temperatures were higher during *rabi*. In contrast, varying photo period did not influence the seed yield. The temperature is around 4^{o}C more in *rabi* may lead to respiratory loss and hence resulted in same yield response between two seasons. According to literature, sunflower is photo insensitive; it performs better in longer growing season with high temperatures [7]. As temperature is high with better radiation interception, plant growth development and physiological processes are usually higher during summer than winter season [7].

Many of the growth parameters such as LAI, LAD and AGR were determined at different crop growth stages both in *kharif* and *rabi*.

Leaf area index (LAI) was maximum at 60 DAS in response to the application of 200% N with growth regulator mixture at wider spacing (60 x 30cm^2) both in *kharif* (5.38) and *Rabi* (5.85), respectively.

Leaf area index was progressively more with a spacing of 45 x 30 cm^2 both in *kharif* and *rabi* (8.20 and 7.69, respectively) due to more leaf area and less available land area for each plant with high plant density. These results are in agreement with Jahangir *et al*., [8] who have reported higher LAI during *rabi* under high plant density.

Leaf area duration (LAD), which is a useful parameter, not only for predicting the efficiency of photosynthetic system but also for dry matter production [9]. The LAD was significantly higher from 60 to 75 DAS and the treatments T$_4$ and T$_{10}$ recorded maximum LAD where 200 % N was applied with growth regulator mixture. However, there was no significant difference observed between the seasons, up to harvest.

Data on absolute growth rate (AGR) showed a non significant difference between the seasons. However, treatment difference could be found out. Treatment with 200 % N with growth regulator mixture (T$_4$ and T$_{10}$) recorded maximum AGR both in *kharif* and *rabi* under 60 x 30 cm^2 and 45 x 30 cm^2 spacing which was on par with T$_3$ (200 % N + PK) and control.

During 45 to 60 DAS, increasing source size by increasing plant density (45 x 30 cm^2) recorded higher AGR (around 16) compared to 60 x 30 cm^2 spacing (13). Nitrogen application significantly increased AGR by increasing overall growth of plants.

Removal of basal leaves (T$_5$ and T$_{11}$) and middle leaves (T$_6$ and T$_{12}$) with both spacing remarkably affected all the physiological growth indices (LAI, LAD and AGR) even in presence of 200 % N. This decrease was more in wider spacing (60 x 30 cm^2) than in narrow spacing (45 x 30 cm^2). Alimohammed and Azizov, [10] reported that the defoliation treatment had significant difference on dry weight and leaf area index.

Higher plant density enhanced LAI, LAD and AGR as LA remains similar on single plant basis. The results suggest that the source per unit area can be improved substantially by agronomic manipulations. However, the increased source size through increased plant density did not improve the seed yield and other yield attributing traits [Table-3] and [Table-4]. Probably the LAI with spacing of 60 x 30 cm^2 would be optimum, above which, there is no further advantage. Therefore, we need to look for erect leaves when the source size is enhanced to increase the productivity.

Yield parameters

Data on yield related traits such as seed filling %, 100 achene weight and total number of seeds indicated that even though when source size was increased by giving lesser plant spacing it did not have effect on yield parameters significantly. The mean values for seed filling was 81.8 % (*kharif*) and 83.61 % (*rabi*) with the spacing 60 x 30 cm^2 and it was 79.57 % (*kharif*) and 82.55 % (*rabi*) with a spacing of 45 x 30 cm^2.

Total numbers of achenes were more with wider spacing (1135 in *kharif* and 1173 in *rabi*) than with 45 x 30 cm^2 spacing (1036 in *kharif* and 1058 in *rabi*, respectively).

With wider spacing, more number of achenes and 100 achene weight per head was due to less plant population that produced significantly bold grains due to less competition and more availability of light, nutrients and feeding area per plant as compared to narrow spacing. The findings are in conformity with the recommendation [11], they demonstrated that 1000 achene weight decreased with increasing plant density.

Higher N levels (T$_2$, T$_3$, T$_4$ and T$_5$) significantly increased the total dry matter under both plant densities. The treatment with growth regulator mixture maintained significantly higher TDM which may be attributed to more number of leaves and plant height leading to increased rate of photosynthesis and maintenance of high leaf area duration during later phase of the crop growth and development.

Table-3 *Influence of increased source size on yield parameters during kharif and rabi in sunflower*

Treatment	Head diameter (cm)		Seed yield (g pl^{-1})		Test weight (100 seeds)		Total number of seeds per plant		Seed filling (%)	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
T$_1$	17.60	17.80	41.47	42.19	4.73	5.43	900.07	1015.27	78.16	82.63
T$_2$	17.40	18.93	43.57	44.10	5.43	5.83	1027.33	1023.47	84.80	86.61
T$_3$	19.00	19.30	45.70	45.80	5.91	5.91	1135.07	1035.07	85.81	85.21
T$_4$	20.10	19.90	47.93	48.33	6.13	6.13	1073.73	1173.73	87.22	89.81
T$_5$	18.40	18.60	36.43	37.77	5.43	5.63	1055.27	1019.40	83.20	82.22
T$_6$	18.20	18.07	33.54	33.47	4.03	4.67	986.33	826.40	71.78	75.20
T$_7$	17.20	17.48	40.37	40.21	4.67	5.50	876.40	996.33	76.12	83.21
T$_8$	17.05	18.33	43.05	43.23	5.80	5.80	1065.40	1008.40	79.46	85.80
T$_9$	18.50	19.23	44.00	44.53	5.90	5.43	1014.67	1017.33	83.55	76.47
T$_{10}$	19.80	19.80	47.00	46.77	6.07	6.07	1036.40	1058.40	85.95	89.33
T$_{11}$	19.30	19.20	35.35	36.37	5.13	5.40	1023.47	1014.67	82.16	86.69
T$_{12}$	18.80	18.80	33.10	33.03	3.80	4.33	862.40	800.07	70.21	73.82
Mean	18.45	18.81	40.95	41.31	5.25	5.51	1012.91	994.98	80.70	82.78
SEm±	0.38	0.26	1.84	1.12	0.19	0.18	23.21	23.21	0.76	0.88
CD @ 5%	1.19	0.77	5.40	3.28	0.55	0.53	NS	NS	2.22	2.59
CV (%)	2.92	2.39	7.17	4.29	5.78	5.56	3.91	3.91	1.59	1.84

However, plant densities only influenced grain yield to little extent. Marginally higher yield was noticed with spacing of 60 x 30 cm^2 compared to narrow spacing of 45 x 30 cm^2. Wider spacing influenced all the yield and yield parameters. This is due to the availability of more light interception and there by higher canopy photosynthesis. This ensured higher dry matter accumulation and thus higher yield.

[Table-5] reveals that with lesser plant density (60 x 30 cm^2), LAD was 3.5 % higher in *rabi* compared to *kharif*. Total biomass was more in *kharif* by 7.8%, whereas there was no much difference in seed yield between the seasons. Among the treatments, application of 200 % N with growth regulator mixture to flower head after anthesis, enhanced LAD by 15.7 %. Though there was no difference in TDM, seed yield was increased by 10%, which in turn increased harvest index (6.7%). In this experiment, there was no significant difference observed for DM/LAD, signifying that enhancing N from 100% to 200% did not improve the leaf area much in sunflower. As expected, defoliation drastically affected all the yield parameters due to reduced source size (LAD). Similarly, application of 200 % N (T$_3$) also enhanced total LAD and seed yield by (13 % and 5 %, respectively). It also increased the TDM, HI and photosynthetic capacity. Thus increase in seed yield may be due to more available leaf area which was on par with T$_4$.

When the row spacing was reduced to maintain more plants per m^2, all the yield parameters were higher compared to lower plant density. The source size, biomass and seed yield were influenced by all the treatments by more than 30 %. It was interesting to note the reduced DM/LAD, which is not a limitation compared to LAD. In this set, application of 200 % N combined with growth regulator mixture influenced total LAD and TDM, increasing the seed yield by 8-9 %. This increase was due to maintenance of higher total LAD which was obtained because of more of number of plants and not by assimilation rate.

Table-4 *Influence of increased source size on yield parameters during kharif and rabiin sunflower*

Treatments	TDM (g pl^{-1})		Harvest index (%)		Oil content (%)		TDM (g m^{-2})		Seed yield (g m^{-2})	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
T_1	104.80	96.41	0.28	0.30	34.56	34.76	576.40	530.25	228.08	232.04
T_2	110.00	98.53	0.28	0.31	36.40	36.31	605.00	541.91	239.63	242.55
T_3	110.05	99.87	0.29	0.31	33.70	34.83	605.27	549.28	251.35	251.90
T_4	110.37	100.95	0.30	0.32	33.60	34.12	607.03	555.22	263.61	265.81
T_5	89.01	87.57	0.29	0.30	33.60	34.12	489.55	481.63	200.36	207.73
T_6	88.05	84.53	0.28	0.28	33.58	33.76	484.27	464.91	184.47	184.08
T_7	103.52	95.83	0.28	0.30	34.23	33.92	766.04	709.14	298.73	297.55
T_8	105.47	97.52	0.29	0.31	37.19	34.92	780.47	721.64	318.57	319.90
T_9	105.90	99.02	0.29	0.31	34.06	34.03	783.66	732.74	325.60	329.52
T_{10}	106.26	99.92	0.31	0.32	33.69	33.65	786.32	732.74	347.80	346.09
T_{11}	86.23	86.43	0.29	0.30	33.64	33.82	683.10	639.58	262.20	269.13
T_{12}	85.67	84.39	0.28	0.28	33.50	33.55	633.95	624.46	244.94	244.42
Mean	99.05	93.60	0.29	0.30	34.08	34.32	661.96	621.13	269.76	271.61
SEm±	3.33	2.06	0.02	0.02	0.36	0.45	1.55	7.18	6.94	4.25
CD @ 5%	9.75	6.06	NS	NS	NS	NS	4.71	22.34	21.59	13.24
CV (%)	5.34	3.65	7.53	7.99	1.94	2.45	1.12	1.63	3.43	2.26

Table-5 *Influence of increased source size on DM/LAD during kharif and rabi in sunflower*

Treatments	Total LAD		DM/LAD	
	Kharif	Rabi	Kharif	Rabi
T_1	149.09	163.11	0.98	0.85
T_2	166.99	175.70	0.92	0.81
T_3	188.71	190.16	0.83	0.77
T_4	193.28	200.05	0.82	0.75
T_5	157.38	157.27	0.80	0.80
T_6	153.12	157.05	0.79	0.75
T_7	198.52	208.62	0.72	0.65
T_8	223.04	227.81	0.67	0.62
T_9	240.76	243.64	0.62	0.59
T_{10}	265.35	259.84	0.58	0.56
T_{11}	206.05	204.74	0.59	0.60
T_{12}	198.09	202.50	0.60	0.58
Mean	**168.69**	**205.16**	**0.58**	**0.56**

The data on oil content revealed no significant differences either among the treatments or between the seasons. However, there was marginally a higher oil content found with 60 x 30 cm^2 spacing compared to narrow spacing. The results are in line with those of Hussain *et al.* [5]. Comparatively higher oil content was recorded in T_2 and T_8 in both seasons where plants were raised according to package of practice. The same trend was noticed in *rabi* also.

In our experiment, defoliation treatment was imposed at the sensitive stage of the crop (ray floret stage) which leads to loss of grain yield due to decreased photosynthesis [12,13]. This also affected 1000 grain weight and seed number per head [14,15].

Leaves on the middle of plants had a more important role on seed yield than leaves on other parts of plant. This result is due to level of photosynthesis activity at the middle leaves [16]. Our results also indicate that removal of middle leaves shows loss of photosynthetic activity near the thalamus causing decreased seed yield. It was also noted mostly that leaves in the top 33 % of the plant in relation to the lower 33 % have an important role in filling the physiological sinks.

Overall results of this experiment reveal that, increasing source size by applying 200% N combined with growth regulator mixture at the recommended plant density (60 x 30cm^2), productivity can be increased up to 10-15 per cent compared to present package of practices. Further increase plant population by reducing the spacing found no effect. Hence, recommended spacing may be followed in sunflower for better light interception and productivity.

Conclusion

On the basis of findings, following conclusions can be made that includes; With wider spacing, seed yield, and yield components like number of achenes, 100 achene weight per head and seed filling percentage were higher due to less plant population that produced significantly bold grains which reduced the competition between the plants and also allowed more light interception and availability of nutrients.

Among the treatments, application of 200 % N with growth regulator mixture to flower head after anthesis, enhanced LAD by 15.7 %. Though there was no difference in TDM, seed yield was increased by 10%, which in turn increased harvest index (6.7%).

Sunflower is a photo-insensitive crop. Hence, in our study seasonal effect was very marginal in all the observed parameters including yield traits.

Overall results of this experiment reveal that, increasing source size by applying 200% N combined with growth regulator mixture at the recommended plant density (60 x 30cm^2), productivity can be increased up to 10-15 per cent compared to present package of practices. Further increase plant population by reducing the spacing found no effect. Hence, recommended spacing may be followed in sunflower for better light interception and productivity.

Abbreviations:

DAS: Days after sowing; GA: Gibberlic acid; BA: Benzyle adenine; NAA: Naphthaleneacetic acid; TDM: Total dry matter.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors

Conflict of Interest: None declared

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