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Effect of fertilizer levels and plant densities on yield, quality and economics of summer sunflower (*Helianthus annuus* L.)

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Abstract
An present field experiment was conducted at the post graduate Research farm, Agronomy section, RCSM College of Agriculture, Kolhapur (MH), India. During March to April 2020 to investigate the effect of fertilizer levels and plant densities on yield, quality and economics of summer sunflower (*Helianthus annuus* L.). The experiment comprised three fertilizer levels *viz,* 45:45:45, 60:60:60 and 75:75:75 NPK kg ha^{-1} and three plant densities *viz,* 30 cm x 30 cm, 45 cm x 30 cm and 60 cm x 30 cm. The experiment was laid out in Factorial randomized block design with four replication. Result revealed that fertilizer levels and plant densities had significant effect on yield *viz,* seed yield, stalk yield, biological yield (q ha^{-1}) was recorded higher by application of fertilizer levels 75:75:75 kg NPK ha^{-1}. All these character were recorded higher under plant density (60 cm x 30 cm). except stalk yield and biological yield. The highest stalk yield and biological yield was recorded in (30 cm x 30 cm). The oil content of summer sunflower was not significantly affected by different fertilizer levels and plant densities. The oil yield was recorded higher by application of fertilizer levels 75:75:75 kg NPK ha^{-1} and plant density (60 cm x 30 cm). The significantly maximum gross and net monetary returns and benefit cost ratio was obtained with fertilizer levels 75:75:75 kg NPK ha^{-1} and plant density (60 cm x 30 cm).

Keywords: Fertilizer levels, planting densities, sunflower, yield, quality and economics

Introduction
Sunflower (*Helianthus annuus* L.) is promising oil seed crop because of its short duration, photo insensitivity and wild adaptability to different agro-climatic regions and soil types. Sunflower can play an important role in meeting out the shortage of edible oil in country. Our country is facing acute shortage of edible oil mainly because of huge demand due to population pressure, raised standard of living and high demand from oil consuming industries. This demand is partly met by import of edible oils. Under such situation it needs to build up self sufficiency in oil production and to meet the increasing demand of consumers. Sunflower oil is considered as a premium when compared to other vegetable oils. Sunflower oil is preferred among the consumers across world due to its health appeal and in India too, sunflower oil is the largest selling oil in the branded oil segment. Sunflower is also a crop of choice for farmers due to its wider adaptability, high yield potential, shorter duration and profitability. In India, the area under oilseed crop is 285.25 lakh ha with production of 328.77 lakh tones and productivity is 1094 kg ha^{-1}. The area under sunflower crop in world is 26.36 million hectares and production is 54.57 million tones with the productivity of 2090 kg ha^{-1}. Where as, in India the area under sunflower crop is 0.23 million ha and production was, 0.17 million tones with the productivity of 760 kg ha^{-1}. In Maharashtra, sunflower is cultivated on an area of 25.1 thousand ha and production is 11.9 thousand tones with the productivity of 475.2 kg ha^{-1} (Anonymous 2019) [2].

Plant densities affect growth characters and yield of sunflower through planting optimum LAI to reduce the competition between plants by more light penetration on plant canopies, consequently enhances photosynthesis process, then increase photosynthesis rate which consequently increase yield per unit area. Moreover, it is usually used in matching crop requirements to the environmental resources available. Furthermore, it is critical practices for determining the most favorable above ground surroundings that allows the plant to obtain the necessary environmental growth factors *i.e.* light, space, water, CO2, and nutrients, which are significant tools to optimize the plant growth and accumulate and production of dry matter as well as consequently maximize the final seeds yield and its quality

(Basha, 2000; Beg *et al.*, 2007 and Biabani, 2010) [3, 5]. In addition, number of plants per unit area play vital role in adjusting the crop environment and assist to improve disease avoidance, therefore modulating number of plant per unit area is the main instrument to improve plant growth and the time required for plant canopy closure and to produce the highest quantity of biomass and seed yield (Khan *et al.*, 2003 and Liu *et al.*, 2008) [13, 9]. Long *et al.* (2001) [14] reported that due to the increasing of interplant competition for space, light, CO2, water, and nutrients and other life factors, the growth characters and yield and its attributes of sunflower plants are probable to decline with raising the number of plants per unit area. While, under the optimum number of plants per unit area, growth, yield, and its attributes were expected to increase. Ali *et al.* (2012) [1] and Ibrahim (2012) [8] declared that plant growth characters, yield and attributes of sunflower plants significantly influenced by plant densities.

Nitrogen is essential constituents protein and chlorophyll, which is present in many other compounds of great physiological importance in plant metabolism such as nucleotides, phospholipids, alkaloids, enzyme, harmones, vitamins etc. it is thus very basic constituents of life. It important dark green colour to plant. Phosphorous plays important role in growth, development and maturity. It helps in flowering and fruiting. Phosphorus is a constituents of nucleic acid, phytine, phospholipids and majority of enzymes, which are of energy in carbohydrate and fat metabolism. It hastens maturity and improves quality of grain, therefore application of phosphorus is must. Potassium in cell sap is involved in enzyme activation, photosynthesis, transport of sugar, protein and starch synthesis. It is known to help crop to perform better under water stress condition through the regulation of the transpiration rate at which plant stomata open and close. It is also known for its role to provide lodging resistance, pest and disease resistance to plants.

Materials and Methods

The field experiments was conducted at Post Graduate Research farm Agronomy section, RCSM College of Agriculture, Kolhapur during March to April 2020 to study the effect of fertilizer levels and plant densities on growth attributes and yield of summer sunflower. The soil type was clay loam with pH of 7.75, organic matter 0.8%, Available nitrogen 236.08 kg ha^{-1}, phosphorus 27.50 kg ha^{-1} and potassium 287.02 kg ha^{-1}. The experiment consisted nine treatments with a combination of three fertilizer levels (45:45:45, 60:60:60 and 75:75:75 kg NPK ha^{-1}) and plant densities (1,11,111; 74,074 and 55,555 plants ha^{-1}) in a Factorial randomized block design.

Crop was planted in a plot size of 25.92 m^{-2} (5.4m x 4.8m) at a spacing of 30 cm x 30 cm, 45 cm x 30 cm and 60 cm x 30 cm. The crop was planted in March 2020. The sunflower crop was fertilized with 45:45:45, 60:60:60 and 75:75:75 kg N: P_2O_5: K_2O ha^{-1}. Full dose of fertilizer were applied at the time of sowing. Nitrogen was applied through urea, phosphorus through single super phosphate (SSP) and potassium through muriate of potash. Gap filling was done at 15th days after sowing and thinning was done at 24th days after sowing, two manual weeding were done throughout the sunflower growing period, irrigation was done four times during the growing period of sunflower.

Five plants were randomly selected from each plot for collecting data on yield attributes and yield. At full maturity, the crop was harvested plot-wise on 21st May and 31st May 2021. Seed and stalk was thoroughly dried plot by plot individually before their weights were recorded. Seed obtained from each unit plot were sun-dried and weighed carefully and the plot yield was recorded in quintal per hectare (q ha^{-1}). Stalk obtained from each unit plot were dried in sun and final stalk yield per plot was recorded in q ha^{-1}.

The experimental data was statistically analyzed by using a standard method of “analysis of variance” as reported by Panse and Sukhatme (1967) [19].

Result and Discussion

Yield and Quality

Seed yield, stalk yield and biological yield were significantly influenced by different fertilizer levels (Table 1). The highest seed yield (13.88 q ha^{-1}), stalk yield (26.50 q ha^{-1}) and biological yield (40.38 q ha^{-1}) was obtained with 75:75:75 kg NPK ha^{-1}, however it was on par with the 60:60:60 kg NPK ha^{-1} and lowest seed yield (11.25 q ha^{-1}), stalk yield (21.00 q ha^{-1}) and biological yield (32.25 q ha^{-1}) was achieved with 45:45:45 kg NPK ha^{-1}. The highest seed yield, stalk yield and biological yield was observed in application if 75:7575 kg NPK ha^{-1} it might due to more availability of plants nutrients leads to the healthy and vigorous growth of the crop. A similar results were also reported by Nasim *et al.*, (2011) [16], Volkan and Kamalttin (2015) [21] and Oad *et al.*, (2018) [17].

The oil content (Table 1) was not significantly affected by different fertilizer levels. The highest oil content (34.83%) was recorded the application of 75:75:75 kg NPK ha^{-1}, then the application of 60:60:60 kg NPK ha^{-1} and 45:45:45 kg NPK ha^{-1}. The oil yield (Table 1) was significantly affected by different fertilizer levels. The highest oil yield (4.85 q ha^{-1}) was recorded the application of 75:75:75 kg NPK ha^{-1}, however it was on par with the 60:60:60 kg NPK ha^{-1} and lowest oil yield (3.84 q ha^{-1}), was achieved with 45:45:45 kg NPK ha^{-1}. Similar results were observed by Chafle *et al.*, (1999) [6] and Pal (2002) [18].

Seed yield, stalk yield and biological yield were significantly influenced by different plant densities (Table 1). The seed yield at planting density 60 cm x 30 cm was the highest (13.83 q ha^{-1}), however it was on par with the planting density 45 cm x 30 cm and the lowest one (11.33 q ha^{-1}) was recorded at 30 cm x 30 cm spacing (Table 1). Due to closer planting density seed yield gradually decreased. Under closer planting density, the rate of yield reduction was in response to decreasing radiation, nutrients, moisture and air. This result is in agreement with that of Kandil *et al.*, (2017). The highest Stalk yield (28.42 q ha^{-1}) and biological yield (39.75 q ha^{-1}) was obtained with the 30 cm x 30 cm, however it was on par with the 45 cm x 30 cm and the lowest stalk yield (19.25 q ha^{-1}) and biological yield (33.08 q ha^{-1}) was recorded in the 60 cm x 30 cm, because least number of plants per unit area than the rest of planting densities. similar results were observed by Gholinezhed *et al.*,(2009).

The oil content (Table 1) was not significantly affected by different plant densities (Table1). The highest oil content (34.75%) was recorded at planting density 60 cm x 30 cm, then the planting density 45 cm x 30 cm and 30 cm x 30 cm. The oil yield (Table 1) was significantly affected by different plant densities. The highest oil yield (4.80 q ha^{-1}) was recorded at planting density 60 cm x 30 cm, however it was on par with the planting density 45 cm x 30 cm and lowest oil yield (3.86 q ha^{-1}), was achieved with the planting density 30 cm x 30 cm. Similar results were observed by Villalobos *et al.*, (2003).

Table 1: Effect of fertilizer levels and plant densities on yield and quality of summer sunflower

Treatment	Seed yield (q ha^{-1})	Stalk yield (q ha^{-1})	Biological yield (q ha^{-1})	Oil content (%)	Oil yield (q ha^{-1})
Fertilizer Levels (N: P_2O_5: K_2O Kg ha^{-1}) (F)					
F1- 75% RDF (45:45:45)	11.25	21.00	32.25	34.17	3.84
F_2- 100% RDF (60:60:60)	12.63	23.42	36.04	34.50	4.35
F_3- 125% RDF (75:75:75)	13.88	26.50	40.38	34.83	4.85
S.E. ±	0.50	1.00	1.14	0.73	0.18
CD at 5%	1.47	2.93	3.34	NS	0.54
Plant Densities (D)					
D_1- 1,11,111 plants ha^{-1} (30 cm x 30cm)	11.33	28.42	39.75	34.08	3.86
D_2 – 74,074 plants ha^{-1}(45 cm x 30 cm)	12.58	23.25	35.83	34.67	4.37
D_3 – 55,555 plants ha^{-1}(60 cm x 30 cm)	13.83	19.25	33.08	34.75	4.80
S.E. ±	0.50	1.00	1.14	0.73	0.18
CD at 5%	1.47	2.93	3.34	NS	0.54
Interaction Effect (F x D)					
S.E. ±	0.87	1.74	1.98	1.27	0.31
CD at 5%	NS	NS	NS	NS	NS
Grand Mean	12.58	23.63	36.22	34.50	4.34

Economics studies

Gross monetary returns, net monetary returns and benefit cost ratio were significantly influenced by different fertilizer levels (Table 2). The highest Gross monetary returns (78,393.75 Rs ha^{-1}), net monetary returns (43,984.58 Rs ha^{-1}) and benefit cost ratio (2.27) was obtained with 75:75:75 kg NPK ha^{-1}and the lowest gross monetary returns (63,562.50 Rs ha^{-1}), net monetary returns (31,828.75 Rs ha^{-1}) and benefit cost ratio (2.00) was achieved with 45:45:45 kg NPK ha^{-1}. A similar results were also reported by Suryavanshi *et al.*, (2012) [20], Khandekar *et al.*, (2013) [12] and Nathan *et al*., (2018) [15].

Gross monetary returns, net monetary returns and benefit cost ratio were significantly influenced by different plant densities (Table 2). The highest Gross monetary returns (78,158.33 Rs ha^{-1}), net monetary returns (45,901.83 Rs ha^{-1}) and benefit cost ratio (2.42) was recorded at planting density 60 cm x 30 cm and the lowest gross monetary returns (64,033.33Rs ha^{-1}), net monetary returns (30,132.92 Rs ha^{-1}) and benefit cost ratio (1.88) was recorded at 30 cm x 30 cm spacing (Table 2). A similar result was reported by Khakwani *et al.*, (2014) [11] and Khazi *et al.*, (2015) [10].

Table 2: Effect of fertilizer levels and plant densities on Economics of summer sunflower

Treatment	Cost of cultivation (Rs ha^{-1})	Gross monetary returns (Rs ha^{-1})	Net monetary returns (Rs ha^{-1})	B: C Ratio
Fertilizer Levels (N: P_2O_5: K_2O Kg ha^{-1}) (F)				
F1- 75% RDF (45:45:45)	31,734.96	63,562.50	31,828.75	2.00
F_2- 100% RDF (60:60:60)	32,815.76	71,331.25	38,514.08	2.17
F_3- 125% RDF (75:75:75)	34,410.64	78,393.75	43,984.58	2.27
S.E. ±	-	2852.38	1570.50	-
CD at 5%	-	8325.53	4583.97	-
Plant Densities (D)				
D_1- 1,11,111 plants ha^{-1} (30 cm x 30 cm)	33,901.28	64033.33	30,132.92	1.88
D_2 – 74,074 plants ha^{-1} (45 cm x 30 cm)	32,802.99	71095.83	38,292.67	2.16
D_3 – 55,555 plants ha^{-1} (60 cm x 30 cm)	32,257.12	78158.33	45,901.83	2.42
S.E. ±	-	2852.38	1570.50	-
CD at 5%	-	8325.53	4583.97	-
Interaction Effect (F x D)				
S.E. ±	-	4940.47	2720.19	-
CD at 5%	-	NS	NS	-
Grand Mean	32,987.12	71,095.83	38,109.13	2.15

Conclusion

1. Based on the present study, it may be concluded that the application of 75:75:75 kg NPK ha^{-1} and sowing 60 cm x 30 cm spacing (planting density 55,555 plants ha^{-1}) recorded higher yield and quality of summer sunflower.
2. The gross monetary returns and net monetary returns and benefit-cost ratio for summer sunflower are found beneficial with the application of the 75:75:75 NPK ha^{-1} and sowing at 60 x 30 cm^2 spacing (plant density 55,555 plants ha^{-1}).

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