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Response of sunflower (*Helianthus annuus* L.) to foliar application of nano fertilizers

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Abstract
A field experiment was conducted at International Crops Research Institute for the Semi-Arid Tropics, Hyderabad during early summer season in 2021 and 2022 to study the "Effect of foliar application of nano fertilizers on yield attributes, seed, and stalk yield of sunflower". The soil was clayey (*Vertisols*) in texture and experiment was laid out in randomized block design with 3 replications and comprised of 12 treatments. The treatments comprise of conventional fertilizers, NPK (19:19:19), nano NPK (19:19:19) and nano boron applied as alone and combinations. Results revealed that application of conventional fertilizers as per recommended dose along with foliar application of nano (19:19:19) N P K @ 0.2% at 30 DAS and 60 DAS + nano boron @ 0.2% at ray floret opening stage (T_7) recorded higher capitulum weight (63.30 and 62.63 g), total number of seeds per capitulum (1102 and 1068), seed yield (1961 and 1915 kg/ha) and stalk yield (4193 and 3918 kg/ha) during both the years and was statistically on par with the treatment - Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS + + nano boron @ 0.2% at ray floret opening stage. Absolute control recorded significantly lower seed yield (758 and 710 kg/ ha) and stalk yield (1684 and 1702 kg/ ha) as compared to all other treatments.

Keywords: Sunflower, foliar application, nano boron, yield attributes, capitulum weight, seed and stalk yield

1. Introduction
Sunflower (*Helianthus annuus* L.) belonging to family Asteraceae is one of the most important oilseed crop in the world. It is primarily grown for edible oil which has high concentration of polyunsaturated fatty acids (Linoleic and oleic acids) and hence considered as good quality from the health point of view (Khan *et al.* 2015) [8]. In India, sunflower occupies the fourth position among oilseed crops in terms of acreage (5.2 lakh hectares) and production (3.35 lakh tonnes) and productivity of 643 kg/ha. Karnataka occupies first position in India with respect to area (1.7 lakh hectares) and production (1.06 lakh tonnes) followed by Andhra Pradesh, Maharashtra, Bihar, Orissa and Tamil Nadu (IIOR, 2018) [6]. In Telangana, sunflower is being grown in an area of 4 thousand hectare, producing 8 thousand tonnes with the productivity of 1154 kg ha^{-1} (IIOR, 2018) [6].

The projected population of India was expected to be around 1.39 billion by 2025 AD and the required oil seeds production and oil requirement will be around 102.3 million tonnes and 39.16 million tonnes by 2050 AD (DRMR, 2015) [4]. Sunflower holds great promise as oilseed crop because of its versatility, photo insensitiveness, short duration, day neutral crop (cultivated in *kharif*, *rabi* and *summer* seasons), and best for contingent crop, high degree of adaptability to different soils and climatic conditions, easy for cultivation, low seed rate, high seed multiplication ratio (1:80), higher market price, drought tolerant, good scope of diversified cropping pattern, problematic soils (salinity), high quality of oil (poly unsaturated fatty acids) content and deep root system. Besides this, a number of hybrids from public and private sectors are available for cultivation and also popular among the farmers. The demand of oil is increasing as the per capita oil consumption is 9.10 kg $person^{-1}$ $annum^{-1}$ in India but production is very low.

Inadequate and imbalanced nutrient supply is amongst the main reason for low productivity of sunflower. Based on leaching losses in addition to volatilization and denitrification losses, the application of urea, DAP, and MOP has been found to have lower fertilizer efficiency, which ranges from 20 to 50% for nitrogen, 10 to 25% for phosphorus, and 70 to 80% potassium (Shaviv, 2000; Chinnamuthu and Boopathi, 2009) [13, 2].

These losses not only contribute to the emission of greenhouse gases but also certain health risks like blue baby syndrome because of eutrophication. Use of nano-fertilizers is one the potential option available for enhancing the nutrient use efficiency and increasing crop yields and also minimize its accumulation in the soil. Nano fertilizers could potentially help in reduction of the quantity of fertilizers applied to crops and reduces fertilizer wastage and minimize environmental pollution (De Rosa *et al*., 2010; Upadhyaya, *et al*., 2017; Singh *et al*., 2017) [3, 16, 14].

Material and Methods

A field experiment was carried out at International Crops Research Institute for the Semi-Arid Tropics, Hyderabad during early summer season in 2021 and 2022. The soil type of experimental site was clayey (*Vertisols*) in texture with pH 8.01, which was medium in available N (241.92 Kg ha^{-1}), high in P_2O_5 (24.72 Kg ha^{-1}) and K_2O (333 Kg ha^{-1}) respectively. The experimental site is located at latitude of 17° 50 N latitude, 78° 26 E longitude and at an altitude of 564 meters above mean sea level. Satellite view of the location of the experimental site was depicted in Fig.1

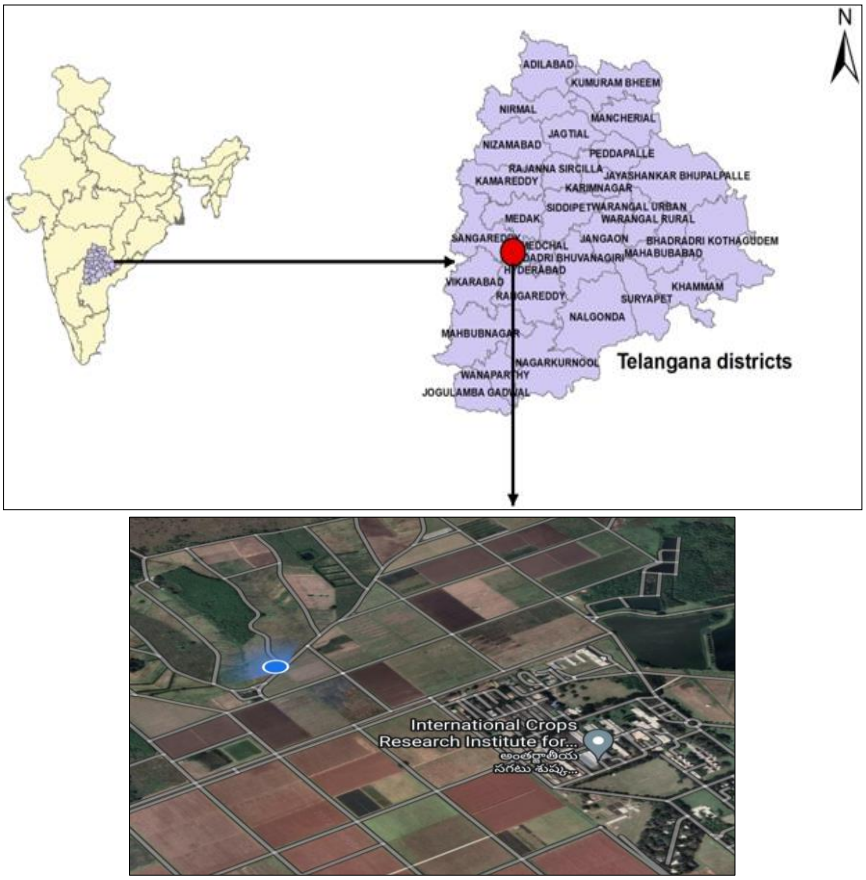

Fig 1: Satellite view of the location of the experimental site

The experiment was laid out in randomized block design and replicated three times and comprised of 12 treatments. Urea, DAP and MOP were used as chemical sources of fertilizer and for nano-fertilizer treatments, Nano NPK (19:19:19) and Nano boron (10.8% boron) were used in the experiment. The recommended dose of fertilizer is 75:90:30 kg NPK/ha. Using scanning electron microscope (SEM) shape and size (morphology) of nano fertilizers were analyzed. The morphology of nano N P K (19:19:19) was circular to irregular (Fig. 2) and nano boron is circular (Fig. 3) with average particle size of 90-280 nm and 50-100 nm respectively.

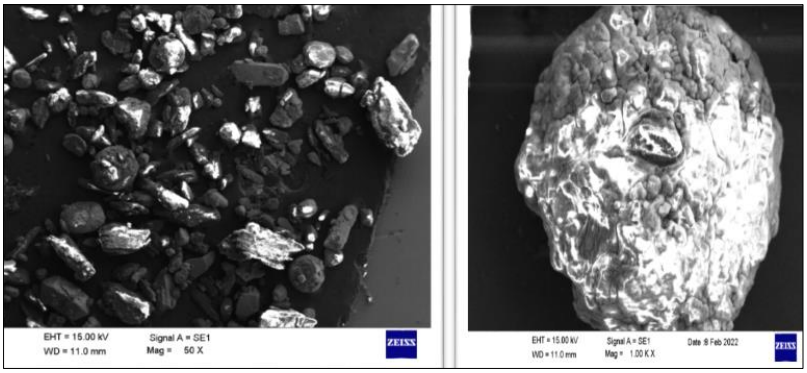

Fig 2: Scanning electron microscope image of nano NPK

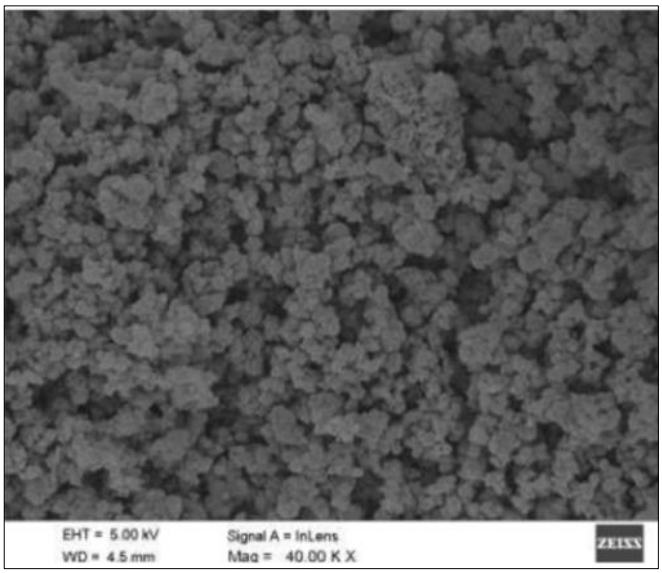

Fig 3: Scanning electron microscope image of nano-boron

The recommended dose of fertilizer is 75 kg N, 90 kg P, 30 kg K/ha. The experiment comprised of 12 treatments *viz.*, T_1-Conventional fertilizers as per recommended dose as soil application,T_2-Conventional fertilizers as per recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS,T_3- Conventional fertilizers as per recommended dose + N P K (19:19:19) @ 0.2% as foliar spray at 30 DAS and 60 DAS, T_4-Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS, T_5-Conventional fertilizers 50% as per Recommended dose + N P K (19:19:19) @ 0.2% as foliar spray at 30 DAS and 60 DAS, T_6-nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS, T_7: T_2 + nano boron @ 0.2% as foliar spray at ray floret opening (RFO) stage, T_8: T_3 + nano boron @ 0.2% as foliar spray at RFO stage, T_9:T_4 + nano boron @ 0.2% as foliar spray at RFO stage, T_{10}: T_5 + nano boron @ 0.2% as foliar spray at RFO stage, T_{11}: T_6 + nano boron @ 0.2% as foliar spray at RFO, T_{12}: Absolute control.

The high yielding popular sunflower hybrid "DRSH-1" was used for experimental purpose and was sown at 60X30 cm spacing, by adopting the recommended seed rate of 5 kg/ha. Weeds were managed by one inter- cultivation at 20-25 days after sowing followed by one hand weeding at 35-40 days after sowing. The plant protection measures were taken up as and when required considering the critical limit of pest incidences. In each plot five plants were randomly selected and tagged to record biometric observations on growth and yield attributes. At maturity, capitulum diameter, head weight, test weight, seed yield and stalk yield were recorded. All the data were subjected to statistical analysis by using WASP 2.0 software.

Results and Discussion

Yield attributes

The results showed that application of conventional fertilizers as per recommended dose along with foliar application of nano (19:19:19) N P K @ 0.2% at 30 DAS and 60 DAS + nano boron @ 0.2% at ray floret opening stage (T_7) recorded higher head weight (63.30 and 62.63 g), total number of seeds (1102 and 1068) and filling percentage (96.59 and 96.10) (Table 1 & 2). However, T_7 was found to be at par with T_9 (Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS and nano boron at ray floret opening stage) with respect to head weight (62.50 and 61.80 g), total number of seeds (1044 and 1008) and filling percentage (96.16 and 95.26) during both the years of experimentation and on mean basis, respectively. This might be due to the reason that foliar application of nano-NPK, which is considered the biological pump for the plants to absorb nutrients, promotes the plant to absorb the nutrients efficiently and in turn enhance the photosynthesis rate. (Wu, 2013 and Ma *et al.,* 2009) [17, 10]. Foliar application of nano boron @ 0.2% at ray floret opening stage met the crop nutrient demand for boron during the pollen development, which may result in increased pollen germination and pollen viability and increasing the translocation of sugars and photosynthates from source to sink which in turn enhances the seed setting percentage number of filled seeds per capitulum and lower chaffiness percentage in the capitulum. This result was in conformity with the findings of Patil *et al*. (2006) [12], Al-Amery *et al*. (2011) [1] and Kavita *et al.,* (2018) [7]. Capitulum diameter and 1000 seed weight was not significantly influenced by different fertilizer treatments. However, highest capitulum diameter (18.54 and 17.97 cm) (Table1) and 1000 seed weight (59.16 and 57.03 g) (Table 3) was recorded with the treatment T_7 than the control and other treatments in comparison during both the years and on mean basis, respectively.

Seed and stalk yield

The data based on two years and on mean basis revealed that treatment (T_7) recorded maximum and significantly higher seed yield (1961 and 1915 kg/ha), stalk yield (4193 and 3918 kg/ha) during both the years and on mean basis, respectively over control (Table 3 Fig.4) and was statistically on par with T_9 (Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS and nano boron at ray floret opening stage seed yield (1936 and 1904 kg/ha), stalk yield (4059 and 3871 kg/ha) followed by T_8 and T_{10} which were at par with each other. The earlier studies also support the findings which reveals that the use of nano-fertilizers increased the N, P & K uptake and resulted in increased biomass production (Liu and Liao 2008) [9]. Increase in seed yield of sunflower may also be through a prolonged photosynthetic capacity during flowering (Tarafdar *et al.,* 2012) [15] and seed set or through improved partitioning from the increased biomass (Al-Amery *et al*., 2011) [1]. Sreelaja (2018) revealed significantly higher yield was recorded with soil application of nano-NPK granules @ 0.33g/plant along with foliar application of nano-NPK @ 0.2% and humic acid in ginger when compared to recommended dose of fertilizers.

Nano boron nutrition improves solubility and dispersion of insoluble nutrients in soil, reduces soil fixation and increases the bioavailability, which significantly improves the nutrient availability, seed setting percentage, test weight and decreases percent chaffiness, by proper fertilization and filling of seeds contribute to the higher economic yield. These results were in accordance with Kavita *et al.* (2018) [7]; Hanumanthappa *et al.* (2019) [5] and Mergheny *et al.* (2019) [11]. Treatment with control recorded significantly lower seed yield (758 and 710 kg/ ha) and stalk yield (1684 and 1702 kg/ ha) as compared to all other treatments. It might be due to nutrient deficiency which in turn resulted in reduction of growth and

development of plant, less photosynthetic activity and less translocation of photosynthates to sink reduced source to sink ratio which further resulted in decreased yield and yield attributes.

Table 1: Capitulum diameter (cm), Head weight (g) and filling (%) of sunflower as influenced by foliar application of nano fertilizers

Treatments	Capitulum diameter (cm)			Head weight (g)			Filling percentage (%)		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T_1: Conventional fertilizers as per Recommended dose as soil application	15.23	14.36	14.46	53.33^{c}	49.96^{c}	51.65^{cd}	84.03^{cde}	87.10^{cd}	85.56^{de}
T_2: Conventional fertilizers as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS	16.57	16.03	16.30	54.22^{c}	51.89^{c}	53.06^{c}	89.28^{abc}	91.36^{abc}	90.31^{bcd}
T_3: Conventional fertilizers as per Recommended dose + N P K (19:19:19) @ 0.2% as foliar spray at 30 DAS and 60 DAS	15.57	14.53	15.05	53.82^{c}	51.29^{c}	52.56^{cd}	86.45^{bcd}	87.86^{bcd}	87.14^{cde}
T_4: Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS	16.40	16.13	16.26	53.96^{c}	51.86^{c}	52.91^{c}	88.44^{bcd}	91.03^{abc}	89.74^{bcd}
T_5: Conventional fertilizers 50% as per Recommended dose + N P K (19:19:19) @ 0.2% as foliar spray at 30 DAS and 60 DAS	14.53	13.73	14.13	51.29^{c}	49.95^{c}	50.41^{d}	81.65^{def}	84.16^{d}	82.90^{ef}
T_6: nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS	11.87	11.50	11.68	45.58^{d}	41.66^{d}	43.63^{e}	76.09^{fg}	77.11^{e}	76.60^{g}
T_7: T_2 + nano boron @ 0.2% as foliar spray at RFO stage	18.54	17.97	18.25	63.30^{a}	62.63^{a}	62.97^{a}	96.59^{a}	96.10^{a}	96.35^{a}
T_8: T_3 + nano boron @ 0.2% as foliar spray at RFO stage	17.30	16.53	16.91	58.80^{b}	58.03^{b}	58.43^{b}	93.74^{ab}	94.03^{a}	93.90^{ab}
T_9: T_4 + nano boron @ 0.2% as foliar spray at RFO stage	18.07	17.86	17.96	62.50^{a}	61.80^{a}	62.15^{a}	96.16^{a}	95.26^{a}	95.73^{a}
T_{10}: T_5 + nano boron @ 0.2% as foliar spray at RFO stage	17.17	16.63	16.90	58.35^{b}	57.83^{b}	58.10^{b}	91.66^{ab}	92.63^{ab}	92.15^{abc}
T_{11}: T_6 + nano boron @ 0.2% as foliar spray at RFO stage	12.53	12.16	12.34	46.00^{d}	44.46^{d}	45.23^{e}	77.38^{ef}	78.33^{e}	77.86^{fg}
T_{12}: Absolute control	10.19	11.27	10.73	29.75^{e}	32.40^{e}	31.06^{f}	70.15^{g}	69.40^{f}	69.76^{h}
SEm(+)	1.83	1.61	1.38	1.08	1.14	1.13	2.32	1.58	1.83
CD (P=0.05)	NS	NS	NS	3.17	3.36	3.21	6.82	4.63	5.18

RFO- Ray floret opening stage, NS- Non significant
In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 2: Total number of seeds per capitulum of sunflower as influenced by foliar application of nano fertilizers

Treatments	Total no. of seeds per capitulum								
	1st year			2nd year			Pooled		
	Filled seeds	Unfilled seeds	Total	Filled seeds	Unfilled seeds	Total	Filled seeds	Unfilled seeds	Total
T_1: Conventional fertilizers as per Recommended dose as soil application	660.52^{de}	124.56^{d}	785.08^{fg}	643.86^{de}	95.22^{d}	739.08^{d}	652.19^{de}	109.89^{d}	762.08^{de}
T_2: Conventional fertilizers as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS	792.22^{c}	94.90^{f}	887.12^{d}	756.22^{c}	70.52^{e}	826.76^{c}	774.22^{c}	87.57^{f}	856.95^{c}
T_3: Conventional fertilizers as per Recommended dose + N P K (19:19:19) @ 0.2% as foliar spray at 30 DAS and 60 DAS	712.02^{cd}	111.56^{e}	823.59^{ef}	678.72^{cde}	93.23^{d}	771.92^{cd}	695.36^{cd}	102.39^{e}	797.75^{cde}
T_4: Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS	s756.70^{c}	98.63^{f}	855.33^{de}	733.37^{cd}	71.96^{ef}	805.33^{cd}	745.04^{c}	85.29^{f}	830.33^{cd}
T_5: Conventional fertilizers 50% as per Recommended dose+ N P K (19:19:19) @ 0.2% as foliar spray at 30 DAS and 60 DAS	617.04^{e}	138.25^{c}	755.30^{g}	603.71^{e}	110.92^{c}	714.63^{d}	610.38^{e}	124.59^{c}	734.97^{e}
T_6: nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS	491.84^{f}	153.67^{a}	645.51^{h}	465.17 ^{f}	133.67^{a}	598.85^{e}	478.50^{f}	143.67^{a}	622.18^{f}
T_7: T_2 + nano boron @ 0.2% as foliar spray at RFO stage	1065.15^{a}	37.51^{i}	1102.67^{a}	1026.82^{a}	41.18^{h}	1068.00^{a}	1045.98^{a}	39.35^{i}	1085.33^{a}
T_8: T_3 + nano boron @ 0.2% as foliar spray at RFO stage	924.25^{b}	61.62^{h}	985.88^{c}	865.99^{b}	54.86^{g}	920.86^{b}	895.15^{b}	58.25^{h}	953.36^{b}
T_9: T_4 + nano boron @ 0.2% as foliar spray at RFO stage	1004.86^{a}	40.07^{i}	1044.94^{b}	960.69^{a}	47.71^{g}	1008.41^{a}	982.78^{a}	43.88^{i}	1026.66^{a}
T_{10}: T_5 + nano boron @ 0.2% as foliar spray at RFO stage	891.71^{b}	81.26^{g}	972.97^{c}	853.26^{b}	66.59^{f}	919.85^{e}	872.50^{b}	73.92^{g}	946.43^{b}
T_{11}: T_6 + nano boron @ 0.2% as foliar spray at RFO stage	501.89^{f}	146.03^{b}	647.92^{h}	475.22^{f}	129.48^{b}	604.70^{h}	488.53^{f}	137.78^{b}	626.33^{f}
T_{12}: Absolute control	371.93^{g}	158.23^{a}	530.16^{i}	335.26^{g}	136.5^{a}	471.82^{f}	353.59^{g}	147.36^{a}	500.99^{g}
SEm+	26.08	2.20	26.23	31.65	3.57	31.65	26.23	2.97	23.69
CD (P=0.05)	76.49	6.46	74.35	92.85	10.49	92.83	74.35	8.46	67.16

RFO- Ray floret opening stage
In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 3: Seed yield (kg/ha), Stalk yield (kg/ha) and test weight (g) of sunflower as influenced by foliar application of nano fertilizers

Treatments	Seed yield (kg/ha)			Stalk yield (kg/ha)			Test weight (g)		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T_1: Conventional fertilizers as per Recommended dose as soil application	1506^{c}	1490^{c}	1498^{c}	3036^{c}	2927^{c}	2982^{c}	53.46	52.19	52.82
T_2: Conventional fertilizers as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS	1590^{c}	1541^{c}	1566^{c}	3216^{bc}	3041^{c}	3129^{c}	56.56	54.49	55.53
T_3: Conventional fertilizers as per Recommended dose + N P K (19:19:19) @ 0.2% as foliar spray at 30 DAS and 60 DAS	1559^{c}	1504^{c}	1531^{c}	3105^{c}	2994^{c}	3049^{c}	55.02	52.82	53.92
T_4: Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS	1573^{c}	1523^{c}	1548^{c}	3186^{c}	3013^{c}	3100^{c}	55.67	53.73	54.70
T_5: Conventional fertilizers 50% as per Recommended dose+ N P K (19:19:19) @ 0.2% as foliar spray at 30 DAS and 60 DAS	1393^{d}	1403^{c}	1398^{d}	2918^{c}	2855^{c}	2886^{c}	52.07	49.84	50.96
T_6: nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS	1075^{e}	1098^{d}	1086^{e}	2446^{d}	2372^{d}	2409^{d}	50.01	47.61	48.81
T_7: T_2 + nano boron @ 0.2% as foliar spray at RFO stage	1961^{a}	1915^{a}	1938^{a}	4193^{a}	3918^{a}	4055^{a}	59.16	57.03	58.10
T_8: T_3 + nano boron @ 0.2% as foliar spray at RFO stage	1746^{b}	1725^{b}	1735^{b}	3646^{b}	3473^{b}	3560^{b}	57.51	55.17	56.34
T_9: T_4 + nano boron @ 0.2% as foliar spray at RFO stage	1936^{a}	1904^{a}	1920^{a}	4059^{a}	3871^{a}	3965^{a}	58.09	55.78	56.94

T_{10}: T_5 + nano boron @ 0.2% as foliar spray at RFO stage	1725[b]	1710[b]	1718[b]	3535[b]	3367[b]	3451[b]	57.21	54.94	56.08
T_{11}: T_6 + nano boron @ 0.2% as foliar spray at RFO stage	1136[e]	1201[d]	1168[e]	2697[d]	2533[d]	2714[d]	51.21	49.14	50.18
T_{12}: Absolute control	758[f]	710[e]	734[f]	1684[e]	1702[e]	1693[e]	44.07	45.13	44.60
SEm (+)	45	48	44	140	130	123	6.29	3.27	3.32
CD (P=0.05)	133	142	123	410	320	317	NS	NS	NS

RFO- Ray floret opening stage, NS- Non significant In a column, means followed by common letters do not differ significantly at 5% level by DMRT

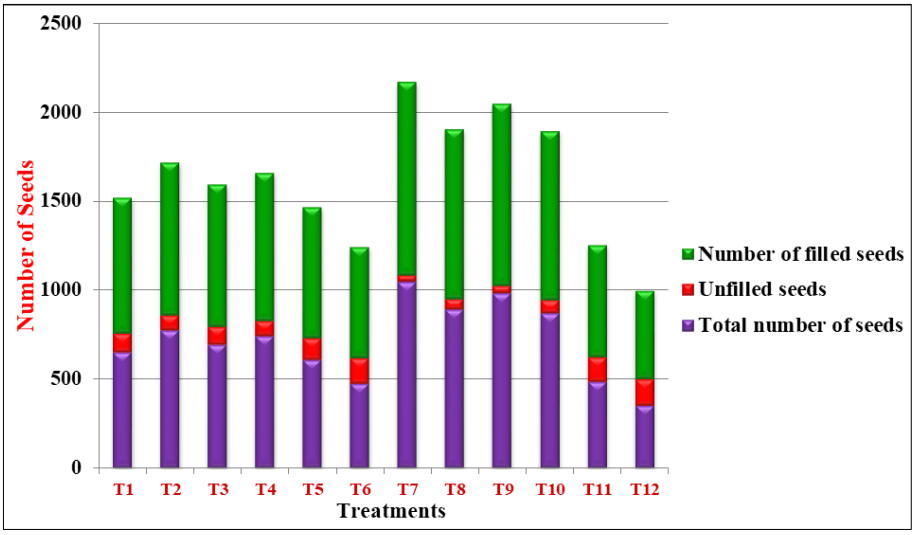

Fig 4: Effect of foliar application of nano fertilizers on filled seeds, unfilled seeds and total number of seeds per capitulum of sunflower

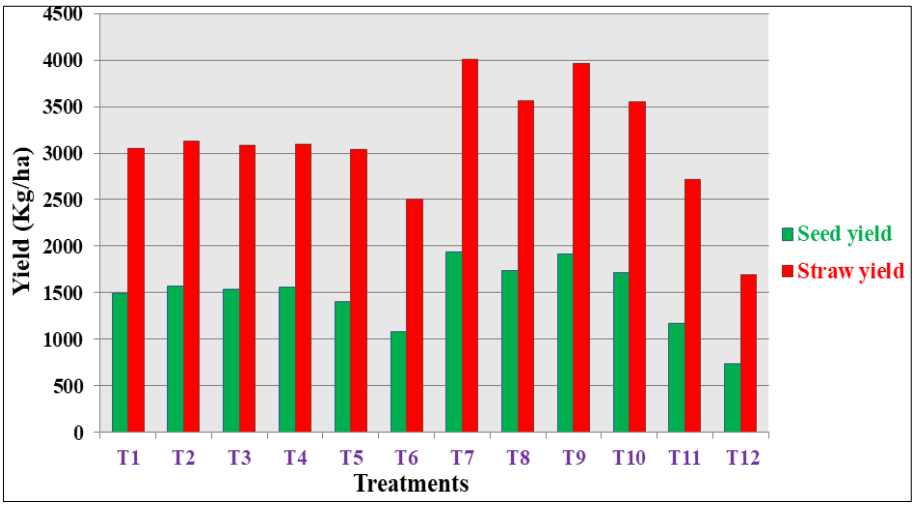

Fig 5: Effect of foliar application of nano fertilizers on seed yield and straw yield of sunflower

Conclusion

The present study findings reveals that treatment T_7 (Conventional fertilizers as per recommended dose along with foliar application of nano (19:19:19) N P K @ 0.2% at 30 DAS and 60 DAS + nano boron @ 0.2% at ray floret opening stage) and treatment T_9 (Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K @ 0.2% as foliar spray at 30 DAS and 60 DAS + nano boron @ 0.2% at ray floret opening stage) was found to be the best treatments in increasing the crop yield and yield attributes of sunflower crop.

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