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Article *in* International Journal of Plant & Soil Science · December 2022

DOI: 10.9734/ijpss/2022/v34i242741

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International Journal of Plant & Soil Science

Volume 34, Issue 24, Page 1102-1111, 2022; Article no.IJPSS.96597
ISSN: 2320-7035

Effect of Combined Application of Non–Nano and Nano Fertilizers on the Growth, Yield and Oil Content of Sunflower under Semi-arid Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i242741

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/96597

Original Research Article

Received: 23/10/2022
Accepted: 30/12/2022
Published: 31/12/2022

ABSTRACT

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 integrated use of Nano and Non–Nano fertilizers on the growth and yield of sunflower under semi-arid conditions". The experiment was carried out using randomized block design with 3 replications and comprised of 12 treatments. The averages of all study indicators were compared according to

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L.S.D test at a probability level of 0.05. Results revealed that application of conventional fertilizers as per recommended dose (75:90:30 kg/ha) along with foliar application of nano (19:19:19) N P K at 0.2% at 30 DAS and 60 DAS + nano boron at 0.2 % at ray floret opening stage (T_7) recorded highest plant height (195,197 and196 cm), number of leaves (27.43, 28.12 and 27.78), leaf area (7632, 7665 and 7649 cm^2 $plant^{-1}$), leaf area index (LAI) (4.24 4.25 and 4.25), and dry matter production (98.96, 97.64 and 98.30 g/plant) at 90 DAS in both the years and on mean basis. However, treatment T_7 was statistically on par with the treatment T_9 - Conventional fertilizers 50% as per recommended dose + nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS and nano boron at ray floret opening stage. Seed yield (1961,1915 and 1938 kg/ha), stalk yield (4193, 3918 and 4055 kg/ha) were also significantly influenced during both the years respectively with the treatment (T_7) was statistically on par with the treatment T_9. Lowest seed yield (758, 710 and 734 kg/ ha) and stalk yield (1684, 1702 and 1693 kg/ ha) and oil content (40.73 %, 39.67% & 40.20) was recorded with the control in both the years and on mean basis.

Keywords: Sunflower; leaf area; LAI; seed yield; oil yield.

1. INTRODUCTION

Helianthus annuus L., the sunflower, is a member of the Asteraceae family and genus Helianthus (Compositae). It is popularly known as *Surajmukhi* in India. The native of the sunflower is reported to be Southern parts of USA and Mexico. Sunflower cultivation was first brought to India in 1969, and with the help of a few imported cultivars from the USSR and Canada, it began to be grown commercially in 1972 - 1973. The sunflower crop is regarded as one of the key sources of vegetable oils not just in our nation but also throughout the world. Sunflower ranks third in the world for total oilseed production, after soybean and peanuts. The peculiar characteristics of sunflower Viz., short duration, photoperiod insensitivity, adaptability to a wide range of soil and climatic conditions, drought tolerance and high quality of edible oil (40–45 percent), sunflower holds great promise as an oilseed crop [1].

Karnataka is the leader in India, in terms of area (1.7 lakh hectares) and production (1.06 lakh tonnes), followed by Andhra Pradesh, Maharashtra, Bihar, Orissa, and Tamil Nadu [2]. In Telangana, sunflower is cultivated on 7,000 hectares of land, yielding 19,000 tonnes at a productivity of 1154 kg/ha [3] . Sunflower oil is considered as premium oil due to presence of oleic acid (16.2%) and linolenic acid (72.5%) with high percentage (60%) of poly unsaturated fatty acids which helps in washing out cholesterol deposition in the coronary arteries of the heart and thus good for heart patients [4]. It is also a good source of calcium, phosphorus, nicotinic acid and vitamin E [5].

The nutrient utilization efficiency of traditional fertilizers is very low. It has been reported that around 40–70 % of nitrogen, 80–90 % of phosphorus, and 50–90 % of potassium content of applied fertilizers are lost in the environment and could not reach the plant which causes significant economic losses [6] [7] [8]. These issues appear to worsen by 2050, when we must feed a population of over 9 billion people. To counteract this scenario, agriculturally dependent countries must implement more advanced technologies, labor-saving practices, and methods. Nanotechnology is a promising tool and has the potential to foster a new era of precise farming techniques and therefore may emerge as a possible solution for these problems. Even in difficult environments, nanotechnology has the potential to increase agricultural yields while remaining environment-tally friendly [9].

Nano fertilizer is considered as appropriate options in comparison to traditional fertilizer for continuous and controlled transport of nutrients in the soil. Plants may easily take nanoscale nutrients [10] and they may display a delayed persuasive period of nutritional flexibility in the soil or on the plant [11] [12].

2. MATERIALS AND METHODS

A field experiment was carried out at International Crops Research Institute for the Semi-Arid Tropics, Patencheru during early summer season in 2021 and 2022. The soil texture of experimental site was clayey with pH 8.01, EC 0.10 dSm^{-1} which was medium in available N, high in P_2O_5 and K_2O, respectively. The experimental site is located at 17^o 50 N latitude, 78^o 26 E longitude and at an altitude of 564 meters above mean sea level. The experiment was laid out in randomized block design and replicated three times and comprised of 12 treatments. Urea, Di Ammonium Phosphate and Murate of Potash 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 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,T2-Conventional fertilizers as per recommended dose + nano (19:19:19) N P K at 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) at 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 at 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) at 0.2% as foliar spray at 30 DAS and 60 DAS, T_6-nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS, T_7: T_2 + nano boron at 0.2 % as foliar spray at ray floret opening (RFO) stage , T_8 : T_3 + nano boron at 0.2 % as foliar spray at RFO stage, T_9:T_4 + nano boron at 0.2 % as foliar spray at RFO stage, T_{10}: T_5 + nano boron at 0.2 % as foliar spray at RFO stage, T_{11}: T_6 + nano boron at 0.2 % as foliar spray at RFO, T_{12}: Absolute control.

The 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 with a plot size 5m x 4.5m. Weeds were managed by hand weeding at 25-30 days after sowing. The plant protection measures were taken up as and when required. A total of five irrigations were given to sunflower crop during the crop ontogeny at 20 days interval starting from pre-sowing irrigation up to the last irrigation. Irrigation was withheld 20 days before harvest.

Data collection: From each plot, five plants were randomly selected and tagged to record periodic biometric observations on growth parameters whereas leaf area was measured at 90 DAS by using leaf area meter and leaf area index was worked out using the following formula [13]. At maturity, seed yield and stalk yield were recorded.

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Statistical analysis: Data that were recorded from the field experiment has been analyzed by using WASP 2.0 (Web Based Agricultural Statistics Software Package) and means separation was done by Duncan’s Multiple Range Test (DMRT).

3. RESULTS AND DISCUSSION

Plant height (cm): At 90 DAS, the (T_7) treatment significantly increased plant height (195, 197, and 196 cm) and was statistically comparable to the (T_9) treatment in terms of plant height (194, 192, and 193 cm, respectively) for both the years and on a mean basis. T_7 was followed by T_8, which was comparable to T_{10} in terms of plant height. Lowest plant height measured in the control (134, 130, and 132 cm) (Table1).

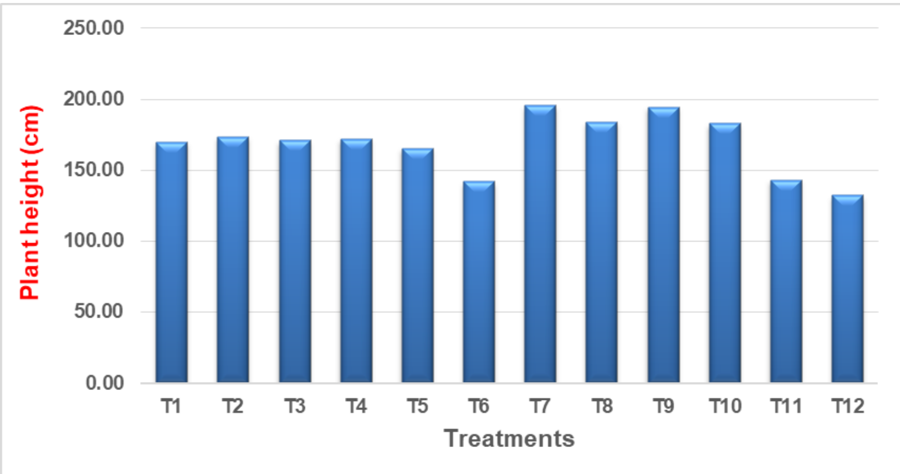

Fig. 1. Plant height (cm) of sunflower (Pooled data) as influenced by foliar application of nano and non-nano fertilizers at 90 DAS

Table 1. Effect of foliar application of nano and non-nano fertilizers on plant height (cm), number of leaves and dry matter production (g/plant) of sunflower at 90 DAS

Treatments	Plant height (cm)			Number of leaves			Dry matter production (g plant $^{-1}$)		
	1^{st} year	2^{nd} year	Pooled	1^{st} year	2^{nd} year	Pooled	1^{st} year	2^{nd} year	Pooled
T1 : Conventional fertilizers as per Recommended dose as soil application	172^{c}	168^{c}	170^{cd}	21.33^{d}	21.65^{cd}	21.49^{de}	76.33^{cd}	77.23^{cd}	76.76^{ef}
T2 : Conventional fertilizers as per Recommended dose + nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS	176^{c}	172^{c}	174^{c}	22.62^{c}	23.40^{c}	23.01^{c}	81.40^{c}	81.13^{c}	81.26^{d}
T3: Conventional fertilizers as per Recommended dose + N P K (19:19:19) at 0.2% as foliar spray at 30 DAS and 60 DAS	174^{c}	169^{c}	171^{cd}	21.46^{cd}	21.73^{cd}	21.58^{de}	80.03^{c}	78.03^{cd}	79.02^{de}
T4:Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS	175^{c}	170^{c}	172^{cd}	21.70^{cd}	22.29^{cd}	21.99^{d}	80.10^{c}	80.43^{c}	80.26^{de}
T5:Conventional fertilizers 50% as per Recommended dose+ N P K (19:19:19) at 0.2% as foliar spray at 30 DAS and 60 DAS	167^{c}	164^{c}	166^{d}	20.93^{d}	20.70^{d}	20.79^{e}	72.64^{d}	74.66^{d}	73.65^{f}
T_6 : nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS	145^{d}	139^{d}	142^{e}	18.13^{e}	17.50^{e}	17.79^{f}	60.93^{e}	58.27^{e}	59.58^{h}
T_7 : T_2 + nano boron at 0.2 % as foliar spray at RFO stage	195^{a}	197^{a}	196^{a}	27.43^{a}	28.12^{a}	27.75^{a}	98.96^{a}	97.64^{a}	98.30^{a}
T_8 : T_3 + nano boron at 0.2 % as foliar spray at RFO stage	184^{b}	183^{b}	184^{b}	25.74^{b}	25.93^{b}	25.83^{b}	87.66^{b}	88.57^{b}	88.12^{c}
T_9: T_4 + nano boron at 0.2 % as foliar spray at RFO stage	194^{a}	192^{a}	193^{a}	27.06^{a}	27.66^{a}	27.36^{a}	94.39^{a}	94.92^{a}	94.62^{b}
T_{10}: T_5 + nano boron at 0.2 % as foliar spray at RFO stage	184^{b}	182^{b}	183^{b}	25.56^{b}	25.56^{b}	25.54^{b}	87.13^{b}	86.95^{b}	87.07^{c}
T_{11}: T_6 + nano boron at 0.2 % as foliar spray at RFO stage	147^{d}	140^{d}	143^{e}	19.10^{e}	18.46^{e}	18.75^{f}	64.90^{e}	62.76^{e}	63.84^{i}
T_{12}: Absolute control	134^{e}	130^{e}	132^{f}	15.27^{f}	15.80^{f}	15.50^{g}	45.61^{f}	44.00^{f}	44.80^{h}
CD (P=0.05)	8.23	8.21	7.50	1.12	1.62	1.30	5.23	5.29	4.73

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

The increase in plant height might be due to the positive role of nano fertilizers in the transfer of carbohydrates from source to sink and influence the process of photosynthesis and stimulation of chlorophyll and enzymatic efficacy that encourage vegetative growth, including plant height [14]. Similarly Ghormade et al. [15] highlighted, nanofertilizers can result in alteration of plant gene expression and associated biological pathways which finally resulted in increase in plant height.

Number of leaves: In both the years and on a mean basis, the T_7 treatment significantly increased the number of leaves per plant at 90 DAS (27.43, 28.12, and 27.78) and was statistically comparable to T_9 throughout both the years and on a mean basis (27.06, 27.66 and 27.36). T_8 came next, matching T_{10} in terms of leaf count, whereas control produced the fewest leaves (15.27, 15.80, and 15.50) per plant. This result is consistent with Alhasany *et al* [16] and El-Hamd and Elwahed [17]. Foliar application of nano boron plays an important role in transporting the processed materials by the process of representation to the effective growth regions of the plant, which encouraged an increase in a number of leaves per plant [14].

Leaf area (cm^2) and leaf area index (LAI): T_7 treatment demonstrated greater leaf area (Fig 2) at 90 DAS (7632, 7765 and 7698 cm^2 $plant^{-1}$ respectively) and LAI (4.24 4.31 and 4.27) in both the years and on mean basis (Table 2). T_7 treatment was statistically comparable to T_9 during both the years and on mean basis (7582, 7486 and 7534 cm2 plant-1 and LAI (4.21 4.15 and 4.18) followed by T_8 which was on par with T_{10}. The control had the lowest leaf area (3616, 3409.34 and 3512.67 cm^2 $plant^{-1}$) and leaf area index (2.01,1.89 and 1.95) over the course of both years and on mean basis.

Foliar application of nano fertilizers, enhanced the nutrient uptake and dry matter accumulation which increased the leaf area. Earlier studies showed that application of nano chelated boron results in higher leaf area in maize compared to control [18]. Increased leaf area index might resulted in achieving more photosynthetic efficiency resulting larger leaf area for harvesting more sunlight. Similar results were in corroboration with the findings of Abdel-Aziz et al. [19]

Dry matter production (g/plant): The highest dry matter production (98.96, 97.64 and 98.30 g/plant) was obtained in T_7 and statistically on par with T_9 (94.39, 94.92 and 94.62 g/plant) during both the years and on mean basis followed by T_8 which was comparable with T_{10}.

The lowest dry matter production observed in control (45.61, 44.00 and 44.80 g/plant) for both the years and on mean basis, respectively (Table1 Fig. 3). This might be due to foliar application of nano NPK and nano boron which increased the bioavailability through root and stomata resulted in overall growth of the plants. The unique properties of nanoparticles such as large surface area and the presence of more reactive oxygen that enhances the photosynthetic rate and metabolic activities. Similar results were also reported by Suriya prabha et al. [20]. According to Liu and Liao [21] observed enhanced uptake of N, P and K leads to the accumulation of biomass due to the application of nanomaterials.

Seed and stalk yield: The data revealed that treatment (T_7) recorded significantly higher seed yield (1961,1915 and 1938 kg/ha), stalk yield (4193, 3918 and 4055 kg/ha) during both the years and on mean basis (Table 3 Fig.4) and was statistically on par with T_9 (1936, 1904 and 1920 kg/ha), stalk yield (4059, 3871 and 3965 kg/ha) during both the years followed by T_8 which was on par with T_{10}. Increase in seed yield of sunflower may also be through a prolonged photosynthetic capacity during flowering and seed set or through improved partitioning from the increased biomass [22] . Nano boron nutrition improves solubility and dispersion of insoluble nutrients in soil, reduces soil fixation and increases the bioavailability, which significantly helps improve 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 Kavitha et al. [23]; Hanumanthappa et al. [24] and Mergheny et al. [25].

Treatment with control recorded significantly lower seed yield (758, 710 and 734 kg/ ha) and stalk yield (1684, 1702 and 1693 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.

Oil content (%): Oil content did not differed significantly due to different treatment applications. However, higher oil content (41.78

%, 41.83 % & 41.80%) was recorded with application of nano (19:19:19) N P K at 0.2% at 30 DAS and 60 DAS and nano boron at ray floret opening stage along with recommended dose of fertilizer (75:90:30 kg/ha) as soil application in both the years and on mean basis. Lowest oil content (40.73 %, 39.67% & 40.20) was recorded with control (Table 3).

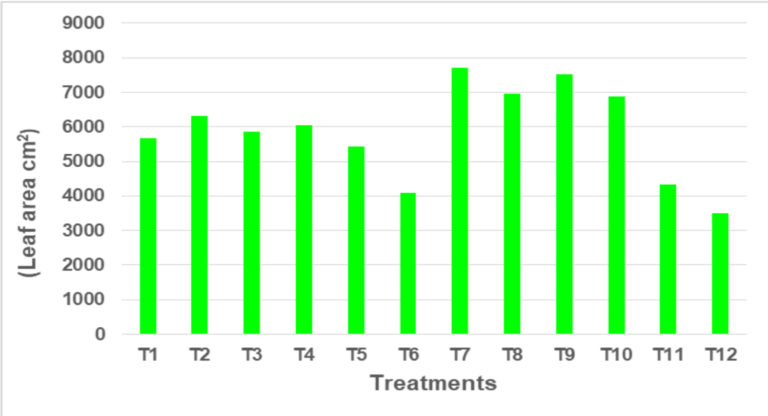

Fig. 2. Leaf area (cm^2) of sunflower (Pooled data) as influenced by foliar application of nano and non-nano fertilizers at 90 DAS

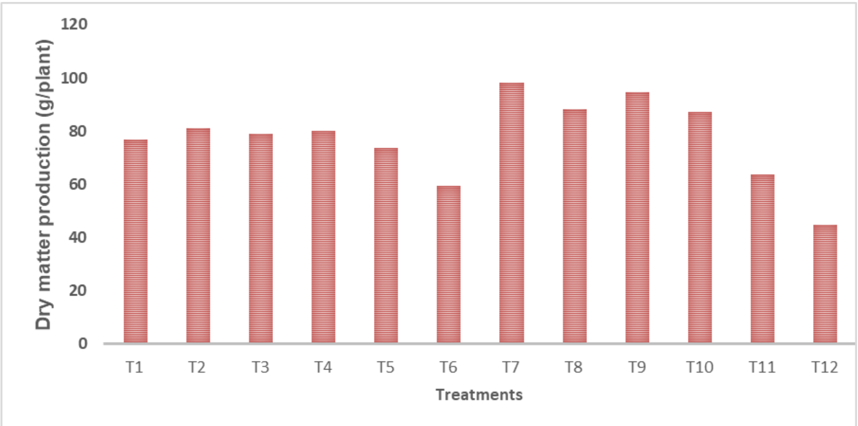

Fig. 3. Dry matter production (g $plant^{-1}$) of sunflower (Pooled data) as influenced by foliar application of nano and non-nano fertilizers at 90 DAS

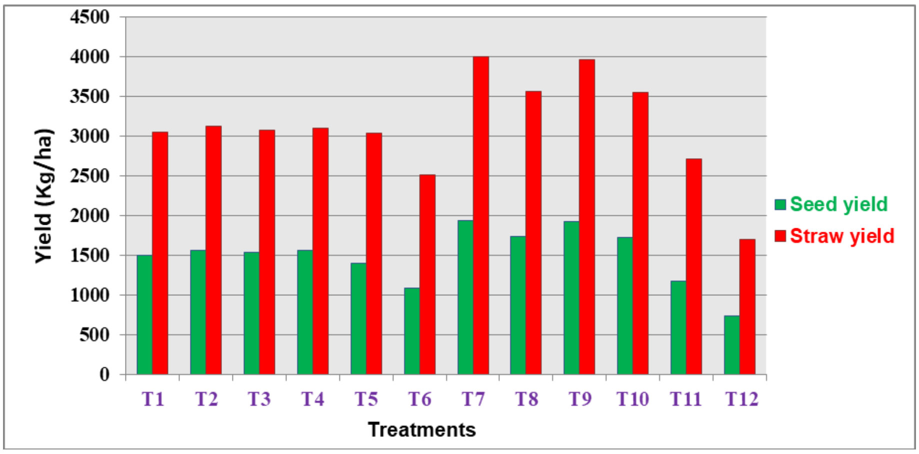

Fig. 4. Seed yield and straw yield of sunflower (Pooled data) as influenced by foliar application of nano and non-nano fertilizers

Table 2. Effect of foliar application of nano and non-nano fertilizers on Leaf area and Leaf area index (LAI) of sunflower at 90 DAS

Treatments	Leaf area (cm^2)			LAI		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T1 : Conventional fertilizers as per Recommended dose as soil application	5749de	5582de	5666de	3.19^{de}	3.10^{de}	3.14^{de}
T2: Conventional fertilizers as per Recommended dose + nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS	6361^{c}	6279^{c}	6320^{c}	3.53^{c}	3.49^{c}	3.51^{c}
T3: Conventional fertilizers as per Recommended dose + N P K (19:19:19) at 0.2% as foliar spray at 30 DAS and 60 DAS	5920^{cde}	5827^{cd}	5873^{d}	3.29^{cde}	3.24^{cd}	3.26^{d}
T4: Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS	6127^{cd}	5951^{cd}	6039^{cd}	3.40^{cd}	3.30^{cd}	3.35^{cd}
T5 : Conventional fertilizers 50% as per Recommended dose + N P K (19:19:19) at 0.2% as foliar spray at 30 DAS and 60 DAS	5508^{e}	5344^{e}	5426^{e}	3.06^{e}	2.97^{e}	3.01^{e}
T_6 : nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS	4207^{f}	3986^{f}	4096^{f}	2.33^{f}	2.21^{f}	2.27^{f}
T_7 : T_2 + nano boron at 0.2 % as foliar spray at RFO stage	7632^{a}	7765^{a}	7698^{a}	4.24^{a}	4.31^{a}	4.27^{a}
T_8 : T_3 + nano boron at 0.2 % as foliar spray at RFO stage	7001^{b}	6907^{b}	6954^{b}	3.89^{b}	3.84^{b}	3.86^{b}
T_9: T_4 + nano boron at 0.2 % as foliar spray at RFO stage	7582^{a}	7486^{a}	7534^{a}	4.21^{a}	4.15^{a}	4.18^{a}
T_{10}: T_5 + nano boron at 0.2 % as foliar spray at RFO stage	6914^{b}	6842^{b}	6878^{b}	3.84^{b}	3.80^{b}	3.82^{b}
T_{11}: T_6 + nano boron at 0.2 % as foliar spray at RFO stage	4369^{f}	4285^{d}	4327^{d}	2.42^{f}	2.38^{f}	2.40^{f}
T_{12}: Absolute control	3616^{g}	3409^{g}	3513^{g}	2.01^{g}	1.89^{g}	1.95^{g}
CD (P=0.05)	482	462	484	0.26	0.25	0.22

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

Table 3. Effect of foliar application of nano and non-nano fertilizers on seed yield (kg/ha), stalk yield (kg/ha) and oil content (%) of sunflower

Treatments	Seed yield (kg/ha)			Stalk yield (kg/ha)			Oil content (%)		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1styear	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}	41.29	41.50	41.39
T_2 : Conventional fertilizers as per Recommended dose + nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS	1590^{c}	1541^{c}	1566^{c}	3216^{bc}	3041^{c}	3129^{c}	41.19	41.35	41.27
T_3: Conventional fertilizers as per Recommended dose + N P K (19:19:19) at 0.2% as foliar spray at 30 DAS and 60 DAS	1559^{c}	1504^{c}	1531^{c}	3105^{c}	2994^{c}	3049^{c}	40.99	41.72	41.36
T_4: Conventional fertilizers 50% as per Recommended dose + nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS	1573^{c}	1523^{c}	1548^{c}	3186^{c}	3013^{c}	3100^{c}	41.43	41.44	41.44
T_5: Conventional fertilizers 50% as per Recommended dose+ N P K (19:19:19) at 0.2% as foliar spray at 30 DAS and 60 DAS	1393^{d}	1403^{c}	1398^{d}	2918^{c}	2855^{c}	2886^{c}	40.95	41.56	41.26
T_6 : nano (19:19:19) N P K at 0.2% as foliar spray at 30 DAS and 60 DAS	1075^{e}	1098^{d}	1086^{e}	2446^{d}	2372^{d}	2409^{d}	41.50	41.22	41.36
T_7 : T_2 + nano boron at 0.2 % as foliar spray at RFO stage	1961^{a}	1915^{a}	1938^{a}	4193^{a}	3918^{a}	4055^{a}	41.78	41.83	41.80
T_8: T_3 + nano boron at 0.2 % as foliar spray at RFO stage	1746^{b}	1725^{b}	1735^{b}	3646^{b}	3473^{b}	3560^{b}	40.79	41.80	41.30
T_9: T_4 + nano boron at 0.2 % as foliar spray at RFO stage	1936^{a}	1904^{a}	1920^{a}	4059^{a}	3871^{a}	3965^{a}	41.49	41.20	41.35
T_{10}: T_5 + nano boron at 0.2 % as foliar spray at RFO stage	1725^{b}	1710^{b}	1718^{b}	3535^{b}	3367^{b}	3451^{b}	41.46	41.75	41.61
T_{11}: T_6 + nano boron at 0.2 % as foliar spray at RFO stage	1136^{e}	1201^{d}	1168^{e}	2697^{d}	2533^{d}	2714^{d}	41.73	41.72	41.73
T_{12}: Absolute control	758^{f}	710^{e}	734^{f}	1684^{e}	1702^{e}	1693^{e}	40.73	39.67	40.20
CD (P=0.05)	134	142	124	411	320	317	NS	NS	NS

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

4. CONCLUSION

The present study highlights the importance of nano fertilizers as foliar application in enhancing the growth, yield attributes, yield and oil content of sunflower. However, furthermore studies should be emphasized on the safety of nano fertilizers on consumers health and ecosystem services.

ACKNOWLEDGEMENT

This research work was supported by IDC-International Crops Research Institute for the Semi - Arid Tropics, Patencheru-Hyderabad, Telangana, India. We acknowledge the financial support of CII-SERB prime ministers fellowship scheme & Tulasi seeds Pvt. Ltd (Guntur), Andhra Pradesh in order to carry out this high end research. The facilities and technical assistance of Dr. Sreenath Dixit, Professor and Head of ICRISAT Development Center and Dr. Prasad Kamdi, watershed manager, IDC-ICRISAT is gratefully acknowleged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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