E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 1564-1571
Received: 06-08-2025
Accepted: 10-09-2025

Chandanshiv PS
M.Sc, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Dr. Ghanbahadur MR
Chairman of advisory Committee & Ex-Professor, Department of Agronomy, Dr. PDKV, Akola, Maharashtra, India

Pande AD
M.Sc, Department of Agronomy, Dr. Panjabrao Deshmukh krishi Vidyapeeth, Akola, Maharashtra, India

Dr. Imade SR
Assistant Professor, Department of Agronomy, Anand Niketan College of Agriculture, Warora, Chandrapur, Maharashtra, India

Corresponding Author:
Chandanshiv PS
M.Sc, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Effect of different levels of nitrogen, phosphorous and zinc sulphate on growth and yield of summer sesame

Chandanshiv PS, Ghanbahadur MR, Pande AD and Imade SR

DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9p.3915

Abstract
Sesame (*Sesamum indicum* L.) is recognized as the "queen of oilseed crops" due to its high oil content, nutritional value, and resistance to oxidative rancidity. Despite its importance, productivity in India and other sesame-growing countries remains low, largely due to suboptimal nutrient management. Nitrogen (N), phosphorus (P), and zinc (Zn) are essential nutrients that influence growth, yield, and oil quality in sesame. The present field experiment entitled *"Response of summer sesame* (*Sesamum indicum* L.) *to the levels of nitrogen, phosphorus and zinc sulphate under irrigated condition"* was conducted during the summer season of 2017 at the Agronomy Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, to evaluate the impact of N, P, and Zn fertilization on growth and development of summer sesame.
The trial was laid out in a randomized block design (RBD) with nine treatment combinations involving 100% and 125% recommended dose of fertilizer (RDF) in combination with three zinc sulphate levels (10, 20, and 30 kg ha^{-1}), replicated thrice. Growth parameters such as plant height, number of branches, functional leaves, leaf area, chlorophyll content, and dry matter accumulation were recorded at different growth stages. Statistical analysis was performed using ANOVA.
Results revealed that plant height, branching, and leaf area increased significantly with higher N and P levels, particularly at 125% RDF. Zinc sulphate application further enhanced growth traits, with 30 kg $ZnSO_4$ ha^{-1} in combination with 125% RDF (T_9) showing the highest values for plant height (110.19 cm), number of branches (4.20), functional leaves (100.7 at 70 DAS), and dry matter accumulation (44.78 g $plant^{-1}$). The positive effects were attributed to improved nutrient uptake, photosynthetic activity, and enhanced metabolic processes.
It can be concluded that applying 125% RDF along with 30 kg $ZnSO_4$ ha^{-1} optimizes growth performance of summer sesame under irrigated conditions, and this integrated nutrient management strategy holds potential for increasing sesame productivity in semi-arid regions.

Keywords: Sesame, nitrogen, phosphorus, zinc sulphate, nutrient management, growth parameters, irrigated condition, oilseed crops

1. Introduction

Sesame [*Sesamum indicum* Linn (Pedaliaceae)] is known as "Queen of oilseed crops" by virtue of excellent quantity of oil and its use in domestic purpose. It is one of the most important ancient edible crops grown next to groundnut & rapeseed-mustard. This crop is probably the most ancient oilseeds known and grown by man. Oilseed crop include large variety of plants which are cultivated primarily for production of oil. Besides providing oil, they are also good source of fat and form highly nutritious human food. Archeological evidence indicates that sesame was found in 'Harappa Culture' the oldest archaeological site in region. Same species are also found in Africa. India now considered as the basic centre of origin. Sesame is presumed to have originated in Africa and latter spread to West Asia to India, China and Japan.

In India sesame seeds are used for oil extraction (78%) edible purpose (20%) and seed purpose (2%) out of that 70% sesame seeds are used for edible purpose such as salad and cooking oil and remaining 30% for toilet soap and manufacture margarine. Sesame is known as benniseed, gingelly, sesame, sisim, til and hawari. The sesame seeds are rich source of food and edible oil, nutritious, healthcare and biomedicine.

Its oil content generally varies from 48to 52% and contain 6355Kcal/kg energy in seeds the seeds are also rich source of proteins (20%-28%), sugars (14-16%), minerals (5-7%) and nutrients like calcium (1.31%) and phosphorous (0.07%). A sesame is regarded fatty acid component / composition of its oil and its resistance to oxidation and rancidity even when stores at ambient air temp. Due to the presence of potent antioxidant sesame seeds are called as "The Seeds of Immortality" with growing health consciousness and sesame has recently immerged as a valuable crop. Sesame is cultivated over an area of more than 7 million ha in world with an annual production of 4 million tones and yield of 535 kg ha^{-1}, India, Myanmar, Sudan, China are the major sesame growing countries.

Since summer sesame is found fertilizer responsive oilseed crop under adequate availability of irrigation water and proper agronomic management. Different sources of nutrients N, P, S and Zn were given like Di-ammonium phosphate, Urea and zinc sulphate for S and Zn requirement. Among the various factors known to augment the crop production per unit area, fertilizer added with suitable agronomic practices play a pivotal role to boost up the crop yield. Among different essential elements, nitrogen is an important element which promotes vegetative growth. Its deficiency retards growth and root development, turns the foliage yellowish or pale green and hastens maturity. Phosphorus is an essential nutrient both as a part of several key plant structure compounds and as a catalysis in the conversion of numerous key biochemical reactions in plants. The presence of phosphorus in the soil encourages plant growth because phosphorus is an essential nutrient. Sulphur as a plant nutrient can play a key role in augmenting the production and productivity of oilseeds in the country as it has a significant influence on quality and development of oil seeds. Sulphur is one of the 16 essential nutrients required by all plants for oil seed production, as one unit of sulphur produces 3-5 units of edible oil (Tandon, 1991) [21]. With this background a field trial was undertaken to study the "Response of summer sesame (*Sesamum indicum* L.) To the levels of nitrogen, phosphorus and zinc sulphate under irrigated condition."

2. Materials and Methods

A field experiment entitled "Response of summer sesame (*Sesamum indicum* L.) to the levels of nitrogen, phosphorus and zinc sulphate under irrigated condition" was conducted in summer season during the year 2017, at Department of Agronomy Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.).

2.1 Soil: To determine the physico-chemical properties of soil, samples from surface 0-30 cm depth were drawn before laying out the experiment from randomly selected spots from the entire experimental area. The soil under the very experimental area was analyzed which was low in available nitrogen (N) medium in available phosphorus (P), and high in available potassium (K).

2.2 Climate and weather: Akola is situated in the subtropical region at 22.42° N latitude and of 77.02° E longitude and at an altitude of 307.4 meters above mean sea level. The climate of the area is semi-arid characterized by three distinct season *viz.*, hot and dry summer from March to May, warm and rainy monsoon from June to October and mild cold winter from November to February.

2.3 Experimental details

2.3.1 Design and Treatments

The experiment was laid out in Randomized Block Design (RBD) with 9 treatment combinations replicated 3 times. The allotment of the treatments to various plot were done randomly.

Treatment details:-

T_1-Control
T_2-100% RDF
T_3-125% RDF
T_4-100% RDF + 10 Kg $ZnSo_4$
T_5-125% RDF + 10 Kg $ZnSo_4$
T_6-100% RDF + 20Kg $ZnSo_4$
T_7-125% RDF + 20 Kg $ZnSo_4$
T_8-100% RDF + 30 Kg $ZnSo_4$
T_9-125% RDF + 30 Kg $ZnSo_4$

Various field operations carried out for the experiment undertaken for summer sesame crop during the crop season.

2.3.2 Sampling technique

In order to represent the plot, five plants from each plot were selected randomly for various biometric observations on growth studies. These selected five plants were labeled properly and all biometric observations were recorded on these plants.

2.3.3 Growth studies

2.3.3.1 Plant height (cm)

The height of the five selected plants was measured in centimeter from the base of the plant to the growing apex of fully opened apical vegetative bud at an interval of 20 days but first observation was taken at 30 days after sowing.

Growth studies		Frequency	Days after sowing
1	Plant height (cm)	5	30, 50, 70, 90 and at harvest.
2	No of leaves $plant^{-1}$	4	30, 50, 70, 90 and at harvest.
3	No of branches $plant^{-1}$	4	50, 70, 90 and at harvest.
4	Leaf area/plant (cm^2)	5	30, 50, 70, 90 DAS
5.	Chlorophyll content index	4	30, 50, 70, 90 DAS
6.	Dry matter accumulation $plant^{-1}$ (g)	5	30, 50, 70, 90 and at harvest.
7.	Days to 50% flowering	1	During flowering.
8.	Days required for maturity	1	At maturity

2.4 Statistical analysis and interpretation of data

The experimental data collected during the course of investigation were statistically analyzed with randomized block design (RBD) programmed by adopting standard statistical techniques of analysis of variance (Gomez and Gomez, 1984).

3. Results and Discussion

3.1 Plant height (cm)

The data pertaining to mean plant height as influenced by various treatments recorded at different stages of crop growth are presented in Table 1, that the mean plant height was progressively increased with advancing age up to harvest.

Initially the rate of plant growth in height was slow during the first 30 days, there after it became rapid between 50 to 70 DAS. This effect might be seen due to application of second remaining 50% split dose of nitrogen after 30 DAS whereas basal dose of 50% nitrogen and phosphorus and $ZnSo_4$ was provided at the time of sowing. The progress in rate of growth was slower down from 70 to 90 DAS and quiet steady from 90 DAS to harvest of the crop. The mean plant height attained at harvest was 106.55 cm.

3.1.1 Effect of nitrogen on plant height

The mean plant height was significantly influenced due to nitrogen levels with increase in 100% (25:25:00) RDF from to 125% (31.25:31.25:00) at 30, 50, 70, 90 DAS and at harvest. 31.25 kg N recorded maximum height of 7.05 cm, 66.65 cm, 99.95 cm and 110.15 cm and 110.19 at harvest respectively, which was found, significantly superior over control and 25 kg N. But (T_4) 25 kg N with 10 kg $ZnSo_4$ and (T_5) 31.25 kg N with 10 kg $ZnSo_4$ found at par. Same case happened with T_8 & T_9 and also with T_6 & T_7 with 100% and 125% N levels along with 20 kg and 30 kg $ZnSo_4$ and found at par and all superior over control, T_3 and T_4. This may due to more availability of nitrogen during crop growth. Nitrogen being the major structural constituent of the plant cell and essential constituent of all the metabolic activities had a positive effect on plant growth and development which might have resulted in optimum cell division and stem elongation. These results are in conformity with the findings of Sarkar A, *et al*. (2006-07) [14].

3.1.2 Effect of phosphorus on plant height

Differences in plant height measured at 50, 70, 90 DAS and at harvest were found significant but at 30 DAS it was non-significant and which are as presented in the Table 1. From 30 DAS to harvest, increased P levels caused considerable increase in plant height. However, there was significant difference in 100% & 125% i.e. 25 kg and 31.25 kg of P levels respectively and 31.25 kg (T_3) found superior than 25 kg (T_3) and control. Same case happened with T_8 & T_9 and also with T_6 & T_7 with 100% and 125% N levels along with 20 kg and 30 kg $ZnSo_4$ and found at par and all superior over control, T_3 and T_4. As effect of P found too slow and it is a slow release nutrient provided through SSP and which is slow release fertilizer and concern is only that P should be available through all the growth stages of life. This may be due to availability of phosphorus slowly during different growth stages. As it act as catalysis in the conversion of numerous key biochemical reactions energy storage and transformation processes in plants. These results are found similar with the results of A Chakraborty (2009-10) [3].

Table 1: Mean plant height (cm) plant^{-1} as influenced by various levels of nitrogen, phosphorus and zinc sulphate

Treatment	30 DAS	50 DAS	70 DAS	90 DAS	At Harvest
T_1-Control	6.53	58.99	74.66	97.38	97.93
T_2-100% RDF	6.19	61.60	80.29	102.12	103.11
T_3-125% RDF	6.55	63.32	87.99	104.97	105.51
T_4-100% RDF + 10 kg $ZnSo_4$	6.53	61.85	90.99	105.02	105.60
T_5-125% RDF + 10 kg $ZnSo_4$	6.88	62.83	91.70	106.60	106.80
T_6-100% RDF + 20 kg $ZnSo_4$	6.77	65.07	94.71	109.80	109.95
T_7-125% RDF + 20 kg $ZnSo_4$	7.05	65.55	97.81	109.62	109.74
T_8-100% RDF + 30 kg $ZnSo_4$	7.20	65.43	99.83	110.11	110.16
T_9-125% RDF + 30 kg $ZnSo_4$	7.05	66.65	99.95	110.15	110.19
SE(m) ±	0.2	0.58	0.68	0.42	0.39
CD @ 5%	NS	1.75	2.04	1.25	1.16
G.M.	6.75	63.48	90.88	106.20	106.55

3.1.3 Effect of zinc sulphate on plant height

A periodical data of plant height furnished in the table 1, Indicated that levels of $ZnSo_4$ at the rate of 10 kg, 20 kg and 30 kg along with 100% and 125% RDF from T_4 to T_9 are at par with the results with each other and superior over control and 100% & 125% RDF. Both the nutrients sulphur and zinc plays significant role in chlorophyll synthesis and pigmentation. Whereas Zn acts as an activator of several enzymes in plants; and is directly involved in the biosynthesis of growth substances such as auxin which is involved in plant growth and cell division. Similar results are obtained by Sanaullah *et al.* (2011) in sunflower and NN Parmar *et al*. (2015-16) with Sulphur application.

3.2. Number of branches^{-1}

The branching was initiated at 40 DAS and increased up to 80 DAS and thereafter there was no increase in number of branches. As observations were recorded in Table-2 from 50 DAS to 90 DAS and at harvest. The mean number of branches at harvest was 3.94.

Table 2: Mean number of branches plant^{-1} as influenced by various treatments

Treatment	50 DAS	70 DAS	90 DAS	At Harvest
T_1-Control	2.19	2.33	3.40	3.40
T_2-100% RDF	2.33	2.67	3.78	3.78
T_3-125% RDF	2.77	3.20	3.93	3.93
T_4-100% RDF + 10 kg $ZnSo_4$	3.05	3.35	3.87	3.87
T_5-125% RDF + 10 kg $ZnSo_4$	3.33	3.57	3.93	3.93
T_6-100% RDF + 20 kg $ZnSo_4$	3.64	3.22	4.12	4.12
T_7-125% RDF + 20 kg $ZnSo_4$	3.55	3.78	4.15	4.15
T_8-100% RDF + 30 kg $ZnSo_4$	3.49	3.67	4.07	4.07
T_9-125% RDF + 30 kg $ZnSo_4$	3.59	3.82	4.20	4.20
SE(m) ±	0.11	0.1	0.1	0.1
CD @ 5%	0.34	0.31	0.3	0.3
General mean	3.11	3.29	3.94	3.94

3.2.1 Effect of nitrogen number of branches plant^{-1}
Mean number of branches plant^{-1} was significantly influenced due to nitrogen levels with 125% RDF. Whereas T_9 provides best result along with T_6 & T_7 significant over control and other and at par with each other. Branching increased slowly from 30 DAS to 90 DAS from 2-5 branches plant^{-1}. As nitrogen helps in the synthesis of chlorophyll and causes increase rate of photosynthesis and cell division and more solar interception during initial days of growth. Results findings are found similar with A Chakraborti (2009-10) and Sonia Shilpi *et al*. (2009) [19].

3.2.2 Effect of phosphorus number of branches plant^{-1}
The application of phosphorus caused significant effect on number of branches plant^{-1} at 50, 70 DAS 90 DAS and at harvest. At all the growth stages, application of T_9 (31.25 kg P_2O_5 and 30Kg $ZnSo_4$), T_6 (25 kg P_2O_5 and 20 kg $ZnSo_4$ ha^{-1}) and T_7 (31.25 kg P_2O_5 and 20 kg $ZnSo_4$) were at par and produced significantly higher number of branches plant^{-1} as compared to T_1 (control) and T_2, T_3, T_4 & T_5. Between T_2 (100% RDF) and T_3 (125% RDF) T_3 found significant. The optimum number of branches significantly influenced with T_6, T_7 and T_9 are 4.00, 4.13 and 4.20 branches respectively. These results are in agreement with A. Chakraborti (2009-10) and VA Khadse *et al*. (2012-13) [8] and Deshmukh SS. *et al*. (2010) [5].

3.2.3 Effect of zinc sulphate number of branches plant^{-1}
10 kg, 20 kg and 30 kg $ZnSo_4$ was provided with 100% RDF and 125% RDF simultaneously in treatments from T_4 to T_9. Among this T_9, T_6 and T_7 found significant over T_8, T_4, control and non-zinc sulphate application; but these three treatments were at par with each other from table 2. These results are in agreement with Tulasi Laxmi Thentu *et al*. (2011-12) and PS De *et al.* (2010) [5] with levels of sulphur in summer sesame.

3.3 Number of functional leaves plant^{-1}
At 30 DAS the number leaves found were non-significant as 7-9 leaves found in every plot despite allocation treatments to plots. Maximum number of leaves were found during 50-70 and 70-90 DAS but maximum at 70 DAS. The highest mean number of leaves observed during 70 DAS is 96.84 in T_9 treatment in table 3. These results are found similar with Sonia Shilpi *et al.* (2011) [19], VA Khadse *et al.* (2011-12) [8].

3.3.1 Effect of nitrogen on number of functional leaves plant^{-1}
Mean number of functional leaves plant^{-1} was significantly influenced due to mulching treatment at all stages of crop growth except 30 DAS and somewhat at harvest. 125% RDF i.e. 31.25 kg N recorded maximum number of leaves plant^{-1}, which was significantly superior over control and 100% RDF i.e. 25 kg N ha^{-1} at 50, 70 and 90 DAS. Also 31.25 kg N with 30 kg and 20 kg $ZnSo_4$ in T_7 & T_9 treatment superior to all and at par with T_6 (25 kg N and 20 kg $ZnSo_4$). The increase in number of leaves might be due to the fact that nitrogen influence and encourage formation of new cells, there by helps in increasing the nutrient absorption and hastening leaf development. These results are found similar with Sonia Shilpi *et al.* (2011) [19], VA Khadse *et al.* (2011-12) [8].

Table 3: Mean number of functional leaves plant^{-1} as influenced by various treatments

Treatment	30 DAS	50 DAS	70 DAS	90 DAS	At Harvest
T_1-Control	8.15	59.480	88.80	57.87	40.27
T_2-100% RDF	8.23	64.817	92.70	62.37	42.40
T_3-125% RDF	8.49	66.210	95.40	64.67	46.39
T_4-100% RDF + 10 kg $ZnSo_4$	8.30	68.217	96.35	66.76	47.63
T_5-125% RDF + 10 kg $ZnSo_4$	8.58	69.393	98.15	68.99	50.74
T_6-100% RDF + 20 kg $ZnSo_4$	8.70	69.953	98.70	69.69	58.84
T_7-125% RDF + 20 kg $ZnSo_4$	9.07	69.907	100.20	69.60	58.14
T_8-100% RDF + 30 kg $ZnSo_4$	8.40	69.813	100.59	70.35	60.28
T_9-125% RDF + 30 kg $ZnSo_4$	8.67	70.763	100.70	71.66	62.01
SE(m) ±	0.21	0.48	0.8	0.43	0.48
CD @ 5%	NS	1.45	2.4	1.28	1.43
General mean	8.51	67.62	96.84	66.88	51.86

3.3.2 Effect of phosphorus number of functional leaves plant^{-1}
The effect of phosphorus on number of leaves plant^{-1} was found significant at all stages of crop growth except at harvest. The maximum number of leaves plant^{-1} was recorded by P2O5 dose at the rate of 31.25 kg ha^{-1} i.e. 125% RDF along with 20 kg and 30 kg $ZnSo_4$, which was significantly superior over all other treatments at 30, 50, 70 and 90 DAS. Also 125% RDF in T_3 better than 100% RDF and control plots. Increase in the level of P_2O_5, number of leaves increased markedly, which might be due to increased rate of cell division and cell enlargement due to energy transfer and photolytic functions due to more uptake of P_2O_5 with more dose than recommended. These results are in conformity with Deshmukh SS *et al*. (2010) [5] and Tulasi Laxmi Thentu *et al*. (2011-12).

3.3.3 Effect of zinc sulphate number of functional leaves plant^{-1}
The effects of zinc sulphate in T_9, T_8 and T_7 on mean number of functional leaves plant-^{1} were found to be significant at all stages growth of sesame excluding 30 DAS and little at harvest. These three treatments T_9, T_8 and T_9 i.e. 125% RDF+30 kg $ZnSo_4$, 100% RDF+30 kg ZnSO4 and 125%RDF+20 kg $ZnSo_4$ had at par in this respect but significant over all other treatments. The difference among the treatments can be seen from the given values at 70 DAS as shown in the table 13. Similar results were obtained by Singaravel R, *et al.* (2010) with zinc sulphate application at 25 hg ha^{-1} and Babhulkar *et al.* (2000) [2] with 30 kg Zn ha^{-1}.

3.4. Leaf area plant^{-1} (dm^2)
From table 4, mean leaf area plant^{-1} increased with the advancement in age of the crop from 30 DAS to 90 DAS. The maximum growth rate in respect of leaf area was 9.16 dm^2 in between 50 to 70 DAS. At 90 DAS the mean maximum leaf area plant^{-1} was 6.36 dm^2 while at 70 DAS 8.05 dm^2.

Table 4: Mean leaf area plant^{-1} (dm^2) as influenced by various treatments

Treatment	30 DAS	50 DAS	70 DAS	90 DAS
T_1-Control	0.27	5.41	6.49	4.39
T_2-100% RDF	0.25	5.73	6.82	4.69
T_3-125% RDF	0.28	6.26	7.18	5.25
T_4-100% RDF + 10 kg $ZnSo_4$	0.30	6.94	7.80	6.06
T_5-125% RDF + 10 kg $ZnSo_4$	0.26	6.93	8.30	6.05
T_6-100% RDF + 20 kg $ZnSo_4$	0.31	6.73	8.80	7.60
T_7-125% RDF + 20 kg $ZnSo_4$	0.32	6.88	8.86	7.89
T_8-100% RDF + 30 kg ZnSO4	0.30	6.85	9.05	7.65
T_9-125% RDF + 30 kg $ZnSo_4$	0.32	7.49	9.16	7.64
SE(m) ±	0.02	0.14	0.15	0.11
CD @ 5%	NS	0.42	0.45	0.31
General mean	0.29	6.58	8.05	6.36

3.4.1 Effect of nitrogen on leaf area plant^{-1}

Leaf area plant^{-1} was significantly influenced due to the treatment of nitrogen at 50, 70 and 90 DAS. However, at 30 DAS and at harvest mean leaf area was not reached to the level of significance. The maximum leaf area plant^{-1} was recorded by T_9 (125% RDF+$ZnSo_4$) which was significantly superior over all the treatments and control at 50 and 70 DAS. But At 50 DAS T_7 And T_8 are at par, T_4 and T_5 are at par and T_4 and T_5 are superior over T_6, also T_8 and T_9 superior over T_6 at 50 DAS. At 70 DAS T_9 is superior over all the treatments and at par with T_8. At 70 DAS T_6 and T_7 are at par. At 90 DAS T_7 is the best treatment over rest others. Whereas T_6, T_8 and T_9 are at par with each other. Enhanced growth of vegetative components of sesame due to nitrogen treatments in the summer season could be attributed to the fact that higher nitrogen provides favorable conditions for growth and development of the plant by providing improved nutrient availability as a result of reduced leaching of nutrients and increased uptake. Results found are similar with Snehangshu Shekhar Nayak *et al*. (2009-10) and S Tripathi *et al*. (2010-11) [25], and R. Sarkar *et al*. (2001-02) [14].

3.4.2 Effect of phosphorus on leaf area plant^{-1}

Phosphorus levels had significant influenced on mean leaf area plant^{-1} at all stages of crop growth except at harvest. The maximum leaf area plant^{-1} was recorded by T_9 (125% RDF+$ZnSo_4$) which was significantly superior over all the treatments and control at 50 and 70 DAS. But At 50 DAS T_7 And T_8 are at par, T_4 and T_5 are at par and T_4 and T_5 are superior over T_6, also T_8 and T_9 superior over T_6 at 50 DAS. At 70 DAS T_9 is superior over all the treatments and at par with T_8. At 70 DAS T_6 and T_7 are at par. At 90 DAS T_7 is the best treatment over rest others. Whereas T_6, T_8 and T_9 are at par with each other. This was mainly due to optimum moisture in root zone which favours uptake of phosphorus, resulting in better growth of the crop. These results are in conformity with GB Unde *et al*. (2014-15) and PS De *et al*. (2010) [5].

3.4.3 Effect of zinc sulphate on leaf area plant^{-1}

Zinc sulphate effect on leaf area plant^{-1} was found significant among different $ZnSo_4$ treatment applied at different rates in which T_9 with 125% RDF+30 kg $ZnSo_4$ and T_8 with 100% RDF+30 kg $ZnSo_4$ and T_6 with 100% RDF+ 20 kg $ZnSo_4$ is superior to all other treatment during all the stages of growth. Results are found similar with the results obtained by R. A. Yadav *et al*. (2005-06) with micro-nutrient Zn Application and NN Parmar (2015-16) with sulphur application.

3.5 Chlorophyll content index plant^{-1} (SPAD)

The general mean from the table showed that the CCI plant^{-1} increased progressively increase up-to 70 DAS and then decreased. The rate of CCI plant^{-1} was highest during 50 and 70 DAS.

Table 5: Mean chlorophyll content index (CCI) plant^{-1} in SPAD as influenced by various treatments

Treatment	30 DAS	50 DAS	70 DAS	90 DAS
T_1-Control	25.03	39.25	45.44	36.84
T_2-100% RDF	24.99	40.37	48.80	37.32
T_3-125% RDF	26.05	41.52	47.66	37.31
T_4-100% RDF + 10 kg $ZnSo_4$	26.55	43.07	50.98	35.54
T_5-125% RDF + 10 kg $ZnSo_4$	25.80	43.46	45.88	38.77
T_6-100% RDF + 20 kg $ZnSo_4$	26.04	43.62	49.00	39.49
T_7-125% RDF + 20 kg $ZnSo_4$	26.43	41.80	50.84	39.51
T_8-100% RDF + 30 kg $ZnSo_4$	26.04	42.19	48.68	39.88
T_9-125% RDF + 30 kg $ZnSo_4$	26.82	42.22	49.62	39.87
SE(m) ±	0.40	0.46	0.55	0.52
CD @ 5%	NS	1.38	1.65	1.57
General mean	25.97	41.95	48.55	38.28

3.5.1 Effect of nitrogen on Chlorophyll content index plant^{-1}

Significant difference had been noticed due to different nitrogen levels at all the dates of observations but at 30 DAS it is much close to each other and non-significant. Treatment T_6 (100% RDF+20 kg $ZnSo_4$) is superior to all the treatments and at par with T_5 (125% RDF + 10 Kg $ZnSo_4$) and T_4 (100% RDF+10 Kg $ZnSo_4$) at 50 DAS. Whereas highest value is obtained 50.98 SPAD and 50.84 SPAD in T_4 & T_7 treatments respectively at 70 DAS. Difference among the chlorophyll content seen at different DAS with different treatments. If considered T_3 without $ZnSo_4$ is at pat with T_2 but significant over control during respective days after sowing. As N is a major part of the chlorophyll molecule and is therefore necessary for photosynthesis. So, it helps to increase chlorophyll content and photosynthesis. These results are in agreement with HE Shehu (2005-06) and PS De *et al*. (2010) [15, 5].

3.5.2 Effect of phosphorus on chlorophyll content index plant^{-1}

Same pattern is followed with levels of P_2O_5 as found in nitrogen levels in which T_6 is superior to all and T_4 is superior to all at 50 and 70 DAS. Trend of chlorophyll content starts declining after 70 DAS up to maturity and almost lost at harvest. As Involved in photosynthesis, respiration, energy storage and transfer, cell division, and enlargement hence produced good results. These results are in agreement with HE Shehu (2005-06) [15] and PS De *et al.* (2010) [5].

3.5.3 Effect of zinc sulphate on Chlorophyll content index plant^{-1}

Effect of zinc sulphate was found quiet significant applied at different rates with 100% and 125% RDF during all stages of growth and non-significant at 30 DAS. Mostly 100% RDF+ 20 kg $ZnSo_4$ (T_6) and 125% RDF+ 10 Kg $ZnSo_4$ (T_5) is superior to all at 50 DAS. Similarly 100% RDF+10 kg $ZnSo_4$ (T_4) and 125% RDF+ 20 kg $ZnSo_4$ (T_7) are significant over all the treatments at 70 DAS. Sulphur is necessary in chlorophyll formation (though it isn't one of the constituents) and Zinc aids plant growth hormones and enzyme system, necessary for chlorophyll production, necessary for carbohydrate formation, necessary for starch formation. Both are effective constituent of chlorophyll formation and improve photosynthetic rate and higher reproductive growth. These results are in agreement with HE Shehu (2005-06) [15].

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

The scrutiny of the data in Table 6 indicates that, there was progressive increase in dry matter accumulation of the plant up to 90 DAS and then decreased. The rate of dry matter accumulation was highest during 30 to 50 DAS producing a total of optimum 0.57 g plant^{-1} and 11.66 g plant^{-1} respectively, which was increased further to the extent of 25.36 g plant^{-1} at 70 DAS and 37.22 g plant^{-1} at 90 DAS and nearly same at harvest, which may be due to leaf senescence but increased in some height due more time gap in harvesting than the actual time after maturity of cultivar.

Table 6: Mean dry matter accumulation (g) plant^{-1} as influenced by various treatments

Treatment	30 DAS	50DAS	70DAS	90DAS	At Harvest
T_1-Control	0.50	9.62	19.73	27.61	27.66
T_2-100% RDF	0.55	9.87	20.50	28.50	28.53
T_3-125% RDF	0.61	10.13	20.97	30.50	30.58
T_4-100% RDF + 10 kg $ZnSo_4$	0.58	12.25	26.17	37.03	37.06
T_5-125% RDF + 10 kg $ZnSo_4$	0.57	11.97	26.63	39.90	39.91
T_6-100% RDF + 20 kg $ZnSo_4$	0.57	12.25	27.17	41.53	41.55
T_7-125% RDF + 20 kg $ZnSo_4$	0.60	12.63	28.22	41.90	41.94
T_8-100% RDF + 30 kg $ZnSo_4$	0.56	12.60	28.42	43.23	43.25
T_9-125% RDF + 30 kg $ZnSo_4$	0.60	13.65	30.50	44.78	44.78
SE(m) ±	0.02	0.18	0.23	0.42	0.42
CD @ 5%	NS	0.53	0.70	1.25	1.26
General mean	0.57	11.66	25.37	37.22	37.25

3.6.1 Effect of nitrogen on dry matter accumulation plant^{-1}(g)

Levels of nitrogen significantly influenced the dry matter accumulation plant^{-1} at all stages of crop growth. 125% RDF and 100% RDF+20kg $ZnSo_4$ (T_6), 100% RDF +30 kg $ZnSo_4$ (T_8) and 125% RDF+ 30 kg $ZnSo_4$ (T_9) produced maximum dry matter plant^{-1}, which was significantly superior over control, 100% RDF and RDF+$ZnSo_4$ treatment at all the stages of crop growth nitrogen which cause rapid vegetative growth of plant, also effective constituent of chlorophyll synthesis and proper development resulting in higher dry weight. The increment of plant growth is associated with the availability of nutrients and moisture supply which may alter with different doses. These results are in conformity with RK Sarkar *et al.* (2001-02) [14].

3.6.2 Effect of phosphorus on Dry matter accumulation plant^{-1} (g)

Dry matter accumulation plant^{-1} was influenced significantly by the treatments of irrigation at all stages of crop growth. 125% RDF+30 kg $ZnSo_4$ (T_9) was recorded significantly higher dry matter accumulation plant^{-1} over rest of the treatments at all stages of crop growth and at par with T_6, T_7 and T_8. 125% RDF (T_3) was also found significantly superior control and T_2 at all stages of crop growth. Dry matter accumulation is the cumulative growth of various plant parts and acts as an important index of efficient photosynthetic activity. Application of phosphorus with irrigation water ultimately reflects on accumulation of higher dry matter in aerial parts. Sarkar A, *et al.* (2006-07) [14].

3.6.3 Effect of zinc sulphate on dry matter accumulation plant^{-1} (g)

The effect of zinc sulphate was found to be significant at all growth stages of crop. Sulphur itself consider as good element for oilseeds in both vegetative and reproductive growth regard. Zinc plays significant role in chlorophyll synthesis and thus helps to increase the rate of photosynthesis. Higher sulphur doses provide good results as T_9, T_8, T_7 and T_6 complimenting with the 100% RDF & 125% RDF doses. Hence provide higher dry matter at harvest despite senescent leaf fall at harvest after maturity. The dry matter accumulation plant^{-1} is the resultant of photosynthesis activity and photo morphogenesis. The dry matter plant^{-1} was significantly influenced due to the $ZnSo_4$ doses and irrigation at all stages of crop growth. Higher doses of $ZnSo_4$ at 20 and 30 kg along with 100% and 125% RDF and desired irrigation frequencies increased in number of branches, number of leaves, leaf area and capsule plant^{-1}, where the photosynthesis produced and accumulated at a higher rate and thus the quantity through the process of plant metabolism ultimately replaced in dry matter production at higher rate. Table 6 indicates that, 100% and 125% RDF with 20 and 30 kg $ZnSo_4$ in from T_6 to T_9 along with irrigation in the given treatment combination recorded the highest dry matter accumulation of 44.78 g at 90 DAS and quiet steady at harvest. Similar results with application of sulphur is found by Tulasi Laxmi Thentu *et al.* (2011-12), PS De *et al.* (2010) [5].

3.7 Number of flower plant^{-1}
Number of flower plant^{-1} found significant at 50, 70, 90 DAS and non-significant at harvest. Number of flowers are found very uneven at different stages of growth and rarely found maximum when it crosses 50% flowering.

3.7.1 Effect of nitrogen on Number of flower plant^{-1}
Data pertaining to number of flower found significant at 50, 70, 90 DAS but non-significant at harvest. At 50 DAS T_6 (100% RDF+ 20 kg $ZnSo_4$) and T_9 (125% RDF+ 30 Kg $ZnSo_4$) with 12.22 and 12.55 respectively superior to all at 50 DAS and its optimum number of flowers obtained during whole growth period. As the flowers of sesame are so soft and delicate, shading problem comes with it. Premature flower drop at deficient moisture and high temperature is serious problem with this. Those increased levels of nitrogen increased the flowering percent but can't overcome this problem.

Table 7: Effect of different treatments on mean number of flowers at different days after sowing

Treatment	50 DAS	70 DAS	90 DAS	At Harvest
T_1-Control	9.333	4.97	2.40	1.87
T_2-100% RDF	9.550	5.73	2.80	1.72
T_3-125% RDF	9.833	6.48	3.70	1.80
T_4-100% RDF + 10 kg $ZnSo_4$	10.867	6.22	3.15	1.58
T_5-125% RDF + 10 kg $ZnSo_4$	10.950	5.23	3.30	1.87
T_6-100% RDF + 20 kg $ZnSo_4$	12.217	6.53	2.47	2.20
T_7-125% RDF + 20 kg $ZnSo_4$	10.933	5.02	2.47	1.87
T_8-100% RDF + 30 kg $ZnSo_4$	11.900	5.57	2.80	2.13
T_9-125% RDF + 30 kg $ZnSo_4$	12.550	8.55	3.93	2.23
SE(m) ±	0.20	0.16	0.14	0.15
CD @ 5%	0.60	0.49	0.42	NS
GM	10.90	6.03	3.00	1.92

3.7.2 Effect of phosphorus on Number of flower plant^{-1}
Effect of P_2O_5 on the number of flowers found significant but not that so desirable one. Premature flower drop and shading of flowers problems remains same those levels of P_2O_5 was increased. So the progressive way is that to study 50% flowering for a yield contributing character as number of flowers varies at different stages of growth because flowering is continued up-to 70 to 80 DAS.

3.7.3 Effect of zinc sulphate on Number of flower plant^{-1}
Effect of zinc sulphate is significant but found similar with levels of nitrogen and phosphorus. The number of flowers plant^{-1} at harvest was non-significant as plant turns into more yielding character as flower turns into capsules and some flowers get dropped.

3.8. Days to 50% flowering
Mean number of days required for 50% flowering was 49.48 days. The effect of levels of nitrogen on days required for 50% flowering was found significant. Similarly non-significant results were obtained by Tulasi Thentu *et al.* (2011-12), PS De *et al.* (2010) and Kalpana Jamdhade *et al.* (2011) and the effect of different phosphorus levels influenced days required for 50% flowering. Similar non-significant results were obtained by PS De *et al.* (2010) [5]. Effect of zinc sulphate also found to be non-significant as it does not influence mean number of days for 50% flowering.

3.9 Days required for maturity
Mean number of days required for maturity are 95.11 days. Number of days required for maturity are found to be non-significant with the different levels of nitrogen, phosphorus and zinc sulphate.

References

1. Mahdi EAR. Response of sesame to nitrogen and phosphorus fertilization in Northern Sudan. J Appl Biosci. 2008;8(2):304-308.
2. Babhulkar PS, Kar D, Badole WP, Balpande SS. Effect of sulphur and zinc on yield, quality and nutrient uptake by safflower in Vertisol. J Indian Soc Soil Sci. 2000;48:541-3.
3. Chakraborty A. Performance of summer sesame (*Sesamum indicum* L.) and estimation of economic and optimum doses of nitrogen and phosphorus in red and laterite soils of West Bengal. J Crop Weed. 2013;9(1):75-8.
4. De PS, Bhale VM, Khadse VA. Quality and economics of summer sesame (*Sesamum indicum* L.) as influenced by irrigation and nutrient levels. Int J Bioresour Stress Manag. 2013;4(2 Suppl):369-71.
5. Deshmukh MR, Duhoon SS, Jyotishi A. Effect of sources and levels of sulphur on seed yield, oil content and economics of sesame (*Sesamum indicum* L.) in Kymore plateau zone of Madhya Pradesh. J Oilseeds Res. 2010;27(1):34-35.
6. Gomez AA, Gomez AK. Statistical procedures for agricultural research. New York: Wiley Interscience; 1984, p. 241-62.
7. Jamdhade K, Chorey A, Tijare B, Bhale VM. Influence of irrigation regimes and nitrogen levels on growth, yield and economics of summer sesame. Int J Curr Microbiol Appl Sci. 2017;6(3):2389-93.
8. Khadse VA, Ghatol PU, Bhale VM. Performance of summer sesame under different irrigation scheduling and nutrient levels in Vidarbha region. Int J Curr Microbiol Appl Sci. 2017;6(11):1988-93.
9. Malik MA, Saleem MF, Cheema MA, Ahmed S. Influence of different nitrogen levels on productivity of sesame (*Sesamum indicum* L.) under varying planting patterns. Int J Agric Biol. 2003;5(4):490-2.
10. Dehnavi MM, Misagh M, Yadavi A, Merajipoor M. Physiological responses of sesame (*Sesamum indicum* L.) to foliar application of boron and zinc under drought stress. J Plant Process Funct. 2017;6(20).
11. Patel HK, Patel RM, Desai CK, Patel HB. Response of summer sesamum (*Sesamum indicum* L.) to different spacings and levels of nitrogen under north Gujarat condition. Int J Agric Sci. 2014;10(1):336-43.
12. Sanaullah, Cheema MA, Wahid MA, Ghaffar A, Sattar A,

Abbas S. Yield response of autumn planted sunflower hybrids to zinc sulfate application. J Agric Res. 2014;52(4).
13. Sarkar A, Zaman A, Rana SK. Performance of summer sesame (*Sesamum indicum* L.) under different irrigation regimes and nitrogen levels. Indian J Agron. 2010;55(2):143-146.
14. Sarkar RK, Saha A. Analysis of growth and productivity of sesame (*Sesamum indicum* L.) in relation to nitrogen, sulphur and boron. Indian J Plant Physiol. 2005;10(4):333-337.
15. Shehu HE. Uptake and agronomic efficiencies of nitrogen, phosphorus and potassium in sesame (*Sesamum indicum* L.). Am J Plant Nutr Fertil Technol. 2014;4(2):41-56.
16. Shehu HE. Effects of manganese and zinc fertilizers on shoot content and uptake of N, P and K in sesame (*Sesamum indicum* L.) on lithosols. Int Res J Agric Sci Soil Sci. 2014;4(8):159-166.
17. Singaravel R, Imayavaramban V, Thanunathan K, Shanmughapriya V. Effect of micronutrients on yield and nutrient uptake of sesame (*Sesamum indicum* L.) in a vertisol soil. Sesame Safflower Newsl. 2002;17:46-8.
18. Nayek SS, Brahmachari K, Chowdhury MR. Integrated approach in nutrient management of sesame with special reference to its yield, quality and nutrient uptake. Bioscan. 2014;9(1):101-105.
19. Shilpi S, Nuruzzaman M, Akhter F, Islam MN, Sutradher GNC. Response of nitrogen and sulfur on the oil content of sesame and nutrient status of soil. Int J Bioresour Stress Manag. 2014;5(1):41-46.
20. Mondal S. Efficiency of sulphur source on sesame (*Sesamum indicum* L.) in red and lateritic soil of West Bengal. Int J Plant Anim Environ Sci. 2016;6(2).
21. Tandon HLS. Fertilizer management in dryland agriculture. New Delhi: FDCO; 1991.
22. Tripathy S, Bastia DK. Irrigation and nutrient management for yield augmentation of summer sesame (*Sesamum indicum* L.). J Crop Weed. 2012;8(2):53-7.
23. Thentu TL, Nawlakhe SM, Mankar DD, Shrinivasrao M, Bhonde GV. Effect of nitrogen, phosphorus and sulphur levels on summer sesame yield, economics and residual fertility status of soil. J Soils Crops. 2014;24(2):306-309.
24. Vani KP, Rekha BK, Divya G, Nalini N. Performance of summer sesamum (*Sesamum indicum* L.) under integrated nutrient management. J Pharmacogn Phytochem. 2017;6(5):1308-1310.
25. Yadav RA, Tripathi AK, Yadav AK. Effect of micronutrients in combination with organic manures on production and net returns of sesame (*Sesamum indicum* L.) in Bundelkhand tract of Uttar Pradesh. Ann Agric Res New Ser. 2009;30(1-2):53-58.