International Journal of Plant & Soil Science

Volume 36, Issue 2, Page 81-95, 2024; Article no.IJPSS.111269
ISSN: 2320-7035

Effect of Irrigation and Nutrient Management Studieson Sesame (*Sesamum indicum L.*)

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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/2024/v36i24367

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/111269

Original Research Article

Received: 25/10/2023
Accepted: 31/12/2023
Published: 25/01/2024

ABSTRACT

Aim: To study the effect of Irrigation and nutrient management studieson Sesame (*Sesamum indicum* L.) in red and laterite soil of Odisha.
Study Design: Treatments included three irrigation levels (I_1: 2 irrigations at 21 and 63 days after sowing, I_2: 2 irrigations at 21 and 42 days after sowing and I_3: 3 irrigations at 21, 42 and 63 days after sowing) are treated in main plot and four nutrient management (N_1: 100% RDF, N_2: 100% RDF + 2 t/ha FYM, N_3: 100% RDF + 2 t/ha FYM + Jeevamrut @250 l/ha and N_4: 75% RDF + 2 t/ha FYM + Jeevamrut @250 l/ha) are treated in sub plot were experimented in split plot design replicate thrice.
Place and Duration of Study: A field experiment was conducted during Summer at khujimahal, Chandaka, Faculty of Agricultural Sciences, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar Odisha.
Results: The results showed that highest seed yield (643.49 kg ha^{-1}), haulm yield (1820.13 kg ha^{-1}) and harvest index (26.04%) was obtained in I_3. N_4 (75% RDF + 2 t/ha FYM + Jeevamrut @250 l/ha) showed second highest seed yield (652.21 kg ha^{-1}), haulm yield (1882.07 kg ha^{-1}) and harvest index

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(25.74%) which is at per with N_3. Highest water use efficiency (2.72 kg ha^{-1} m^{-1}) was calculated in I_2N_3.
Conclusion: cultivation of sesame under75% RDF + 2 t/ha FYM + Jeevamrut @250 l/ha with 2 irrigations at 21 and 42 days after sowing proved better in terms of yield, economics and water use efficiency.

Keywords: Irrigation; nutrient management; sesame; yield; water use efficiency.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is generally known as til and it is called as "queen of oilseeds", has been known to the earliest edible oilseeds used by human. It is grown in wide range of environment covering semi-arid tropics, subtropics to temperate regions. It belongs to the family pedaliaceae, which consists of about 16 genera and nearly 60 species. Sesame is known variously as Till, Simsim, Beniseed, Gingelly, Gergelimetc and it is one of the most important oilseed crops grown extensively in India. Sesame stands 2nd in position, next to groundnut among the six major oilseed crops in case of production of edible oil are concerned. Its oil content varies from 46 to 52% and protein content between 20 to 26%. On an average, 70% of the sesame produced in India is used for oil extraction while, 20% for domestic uses like, culinary and confectionary purposes in manufacturing of paint perfumed oils, preparation of sweet candies as condiments, pharmaceuticals and insecticides [73-76]. The fatty acid composition in sesame like, linoleic, oleic, stearic and palmitic acids are its major constituents. The sesame oil is highly resistant to oxidative rancidity and also characterized for its stability and quality. Sesame oil is also known to as "poor man's substitute for ghee". The byproduct of sesame cake obtained from milling industry is rich in protein, vitamin (Niacin) and minerals (Ca and P). The sesame cake contains 6.0-6.2% N, 2.0-2.2% P [77-81].

Despite of being such an important oilseed crop, the average productivity is quite low in comparison to global as well as national level [67-72]. Generally, sesame is cultivated as sole or mixed crop during kharif, rabi and also in summer season in all the districts of the Odisha. Low productivity occurring is due to use of in proper rate of fertilizer, poor management and cultivation of sesame in marginal and sub-marginal lands [55-59]. Mainly, poor irrigation management and deficiency of nutrient such as nitrogen, phosphorus, potassium and micronutrient is predominant. Variety, TKG-21 is suitable for summer cultivation [26-31]. The major reasons for low yield of sesame in the country are its cultivation on marginal lands under dryland conditions, without proper use of fertilizers, inadequate plant stand and lack of proper water management [47-54]. The scope for increasing the area under irrigation in the state is limited and in dry farming regions under rainfed condition only the practice which might contribute to production and productivity by way of better and efficient utilization of available resources and can ensure maximum conservation of soil and water [22-25].

Considering limited water supply, growing drought- tolerant crops is a useful strategy in many situations. Sesame is a one of the important drought-resistant crops and suitable for cultivation in semiarid areas than other arable crops. Unlike other crops, grain filling period is the most important in determining productivity of sesame [32-38]. Although the test weight is genetic characteristic, environmental stresses such as drought can cause yield loss and decrease test weight. The integration of chemical fertilizers with organic manures have been found to be quite promising not only in maintaining higher productivity but also providing greater stability in crop production [1]. A judicious combination of organic and inorganic fertilizers can maintain long term fertility and sustain higher productivity of crops. Considering the low nutrient status of soil (particularly N and P as well as organic carbon) there is need of integrated nutrient management (organic and inorganic fertilizer), in a balanced proportion than which either alone or in combination can increase and sustainable growth and yield of crops [39-46,60-66]. Therefore, the present study aimed to determine the compatibility of sesame. Therefore, the present investigation entitled "Irrigation and nutrient management studies on summer sesame (*Sesamum indicum L.*)" was carried out with theobjectives i.e., to compare different irrigation management on growth parameters and yield& to evaluate the performance of sesame crop under different nutrient management.

2. MATERIALS AND METHODS

A field experiment entitled “Irrigation and nutrient management studies on summer sesame (*Sesamum indicum* L.)”, during Summer at khujimahal, Chandaka, Faculty of Agricultural Sciences, Siksha ‘O’ Anusandhan (Deemed to be University), Bhubaneswar Odisha. experiment was formulated to know the performance of sesame in South east coastal plain zone of Odisha under different irrigation levels and nutrient management. The experiment was laid out in split-plot design. Number of irrigation regimes was three were taken in main plot treatment and nitrogen sources (integration) were four were taken as subplot treatment. So, for each experiment, numbers of total treatment combinations were 12 and replicated thrice. The material used and techniques adopted for collection of soil, plant samples, analytical methodologies followed and statistical methods adopted. In main plot 3 irrigation regimes are conducted i.e., I_1- 2 irrigations at 21 and 63 days after sowing I_2- 2 irrigations at 21 and 42 days after sowing and I_3-3 irrigations at 21, 42 and 63 days after sowing and in sub plot 4 doses of nutrients are applied i.e., N_1- 100% RDF, N_2- 100% RDF + 2t/ha FYM, N_3- 100% RDF + 2t/ha FYM + Jeevamrut @250l/ha, N_4- 75% RDF + 2t/ha FYM + Jeevamrut @ 250l/ha whereas RDF = 30:15:15 (N:P2O5:K2O) kg $ha^{-1}$is considered. To estimate the various physico-chemical properties of soil, soil samples (0-15 cm depth) were collected from different spots of the experimental field systematically in a zigzag manner from the field and bulked to form a composite sample prior to land preparation and also after harvest of the crop from each plot. The composite soils sample thus collected were air dried, sieved through 2 mm sieve and stored in polythene bag, subjected to mechanical, physical and chemical analysis for obtaining initial analysis data using standard analytical procedure. The soil type belongs to order Inceptisol, with sandy loam texture. The initial pH and EC were recorded 5.65 and 7.33 ds m^{-1} respectively. The soil available nitrogen, phosphorus, potassium and organic carbon were found to be 137.98 kg/ha, 20.29 kg/ha, 194.16 kg/ha and 0.30% respectively. After harvesting of crop, the soil samples (0-15cm) were collected from each plot. Sampling was done with the help of spade in order to prevent contamination. The soil samples were air dried, sieved through 2 mm sieve and stored in polythene bag for analysis of various physical and chemical property. The crop was harvested after attaining physiological maturity at 85 days after sowing. The stover from each treatment plot was harvested and sun dried. The weighed stover was recorded and expressed in kg ha^{-1}. The Samples were oven dried in hot air oven at 60° c up to constant weight or till the samples become moisture free. The over dried weight was recorded. The over dried stover and grain samples were then powdered in a grinder and stored for analysis.

3. RESULTS AND DISCUSSION

3.1 Crop Growth Rate

Water management significantly affects most of the crop growth parameters. Crop growth rate (CGR) significantly responded to water management as well as different nutrient treatments differences. There is no significant difference among the treatment combination on Crop growth rate in different date’s interval. Irrespective of nutrient management, I3 produced significantly highest crop growth rate (CGR) 6.45 gm-2 day-1 followed by I2 (6.23 gm-2 day-1) during 60 to 90 DAS and 8.12 gm-2 day-1 followed by I2 (7.68 gm-2 day-1) during 90 DAS to maturity. In 100% RDF treated plot (N1) found lowest CGR (5.67 gm-2 day-1 and 16.48 gm-2 day-1) during 60 to 90 DAS and 90 DAS to maturity respectively (Table 1). There is no significant difference among the treatment combination on Crop growth rate in different observation dates. From the study the positive response of sesame to application of irrigation in critical growth stages was also observed by Garai and Datta, [2]. The present result showed that improved vegetative growth due to combined application of FYM with fertilizers which is similar to the findings of Jain et al. [3].

3.2 Number of Branches/Plant

The number of branches per plant of sesame crop is registered significant variations under different treatments are presented in Table 2. The branches numbers differed significantly with different nutrient management possibly due to their genetical traits. There is significant variation of number of branches count per m2 in different irrigation levels. I3 produced statistically highest number of branches per m2 (4.4) at maturity, whereas, lowest was founded in I1 (3.9). Integrated nutrient management showed non-significant variation of amount of branches/plant. The observed data showed that, there are no significant differences among the treatment combination on amount of branches/plant at

different observation dates. Number of branches/plants differed significantly due to change in irrigation levels was also reported by Bhatti et.al (2014). The number of branches is found highest in combined application of inorganic and organic fertilizers Sahu et al. [4]. This similar result also observed in present research work.

3.3 Yield Attributing Characters

Number of capsules per plant, test weight (1000 grain weight) etc. collectively shapes up the grain yield of sesame crop. Recorded data of capsules per plant, capsule length, no of seeds/capsule and test weight under different treatments have been furnished in Table 2 and Table 3. Number of capsules/plant (42.2), capsule length (2.9 cm), number of seeds/capsule (54) and test weight (3.45 g) counted to be highest in I3 regimes. Among different nutrient management, 100% RDF + 2 t/ha + Jeevamrut @250 l/ha (N3) produced maximum number of capsule/plant (41.4) and number of seeds/capsule (53) represented in Table 2. There is no significant difference on length of capsule, number of seeds/capsule and test weight under different treatments combination at 105 DAS (maturity).

The significant difference of number of seeds/capsules among the different nutrient management found highest in N3 (53) followed by N4 (51) whereas, significantly least number of seed/capsules recorded in N1 (48) (Table 2). Test weight counted to be highest in I3 treatment (3.45 g) and lowest in I1 treatment (3.27 g). Tabulated result reflected that the significant difference of amount of capsules/plant among the treatment combination at maturity stage. The observation proved that different nutrient management at different irrigation regimes i.e. (I3N3) produced highest number of capsules/plant (44.3) and lowest number is found in I1N1 (34) (Table 4). Sahu et al. [4] observed that the number of capsules/plants is found highest in combined application of inorganic and

Table 1. Effects of irrigation and nutrient management on crop growth rate (gm-^{2}day-^{1}) of summer sesame

Treatments	30-60DAS	60-90DAS	90-105 DAS (At maturity)
I_1(2irrigationsat21and63days aftersowing)	5.60	4.93	7.20
I_2(2irrigationsat21and42days aftersowing)	5.77	6.23	7.68
I_3(3irrigationsat21,42and63daysaftersowing)	5.78	6.45	8.12
SEm(±)	0.04	3.4	0.13
CD(0.05)	1.5	1.06	0.48
$N_1$100%RDF	5.21	5.67	6.48
N_2(100% RDF+ 2 t/ha FYM)	5.80	5.81	7.85
N_3(100%RDF+2 t/haFYM+ jeevamrut@250l/ha)	6.35	5.85	9.03

Table 2. Effects of irrigation and nutrient management on number of Branches/plant of summer sesame

Treatments	60 DAS	90 DAS	105 DAS (At Maturity)
I_1(2irrigationsat21and63days aftersowing)	3.7	3.8	3.9
I_2(2irrigationsat21and42days aftersowing)	3.9	4.2	4.2
I_3(3irrigationsat21,42and63daysaftersowing)	4.1	4.2	4.4
SEm(±)	0.1	0.1	0.1
CD(0.05)	0.3	0.4	0.4
$N_1$100%RDF	3.6	3.7	3.9
N_2(100% RDF+ 2 t/ha FYM)	3.9	4.0	4.1
N_3(100%RDF+2 t/haFYM+ jeevamrut@250l/ha)	4.2	4.3	4.4
N_4(75%RDF+2 t/haFYM + jeevamrut@250l/ha)	4.0	4.2	4.3
SEm(±)	0.1	0.1	0.1
CD(0.05)	0.2	0.3	0.4

Table 3. Effects of irrigation and nutrient management on number of capsules/plants, length of capsule (cm), number of seeds/capsule and test weight (g) of summer sesame

Treatments	Number of capsules/plants	Length of capsule(cm)	Number of seeds/capsules	Test Weight (g)
I_1(2 irrigationsat 21and 63 days aftersowing)	36.1	2.6	47	3.27
I_2(2 irrigationsat 21and 42 days aftersowing)	40.1	2.8	51	3.37
I_3(3irrigationsat21,42and63days aftersowing)	42.2	2.9	54	3.45
SEm(±)	0.9	0.03	1.3	0.02
CD(0.05)	2.8	0.2	4.0	0.05
$N_1$100%RDF	37.6	2.7	48	3.27
N_2(100% RDF+ 2 t/ha FYM)	39.5	2.7	50	3.34
N_3(100%RDF+2 t/haFYM +jeevamrut @250l/ha)	41.4	2.8	53	3.45
N_4(75%RDF+2 t/haFYM +jeevamrut @250l/ha)	39.4	2.8	51	3.39
SEm(±)	0.4	0.1	0.9	0.09
CD(0.05)	1.3	0.4	2.8	0.36

Table 4. Interaction effects of irrigation and nutrient management on amount of capsules/plant of summer sesame

Irrigation	Nutrient management				Mean
	N_1	N_2	N_3	N_4	
I_1	34.0	37.0	37.3	36.1	36.11
I_2	38.3	39.7	42.4	40.0	40.12
I_3	40.6	41.9	44.3	42.1	42.22
Mean	36.1	39.5	41.4	39.4	

CD (P=0.05) Irrigation at the same nutrient management = 2.4Nutrientmanagementat same irrigation =2.1

organic fertilizers. This result is in concurrent with present study. The number of capsules per plant and 1000 seed weight increased as irrigation frequency and nitrogen fertilizer rates were increased. Our result is also similar to the findings of Mondal et al, [5]. The beneficial effect of nitrogen on test weight of sesame was also observed by Malik et al. [6]. Ghosh and Biswas [7] observed that the crop receiving irrigation both at branching and flowering stages benefited more from applied water in terms of yield and yield attributes. My results are in agreement with this finding.

3.4 Yield

Results revealed significant differences in seed yield due to the different water management treatments (Table 4) where the lowest seed yield (597.33 kg ha-1) were recorded for I1 regimes. 3 irrigations at 21, 42 and 63 days after sowing (I3) resulted the highest seed yield of 643.49 kg ha-1 followed by I2 (629.84 kg ha-1). The maximum amount of seed yield in I3 may be due to producing maximum number of capsules per plant on account of higher availability of water. Irrespective of irrigation levels, in different nutrient management, 100% RDF + 2 t/ha FYM + Jeevamrut @250 l/ha (N3) produced highest yield (652.21 kg ha-1) followed by N4 (632.99 kg ha-1) whereas, 100% RDF (N1) gave significantly lowest seed yield (591.94 kg ha-1).

From the result it was found that, application of three numbers of irrigations at branching, flowering and seed development stages increased yield attributing characters and yield of summer sesame crop. The same was reported by Dutta et al. [8]. Choradia and Gaur, [9] reported that under limited water supply, higher yield can be obtained by proper irrigation scheduling which is in concurrent with it present result. The increase in growth and yield of

sesame by irrigation could be attributed to the fact that timely supply of adequate water to plants results in greater photosynthesis which ultimately leads to increased dry-matter production (Kirkham, 2005). T. Oweis, H. Zhang, and P. Mustafa, [10] also observed that the amount of irrigation water applied significantly affected the seed yield of sesame.

Significantly highest seed yield recorded in I3N3 treatment (676.5 kg ha-1) followed by I2N3 (654.6 kg ha-1) and I3N4 (654.2 kg ha-1) and lowest in I1N1 treatment (570.00 kg ha-1) (Table 4). Data from Table 4 showed that, the higher haulm yield was found in I3 (1828.13 kg ha-1) followed by I2 (1794.27 kg ha-1). The observed data also showed that, haulm yield differs with variation of nutrient management. It is recorded highest in N3 (1882.07 kg ha-1) followed by N4 (1878.82 kg ha-1). Haulm yield recorded in I3N3 treatment (1930.6 kg ha-1) (Table 5).

Haulm yields preferably increased with integrated nutrient management with fertilizer + FYM + Jeevamrut was also reported by Raman and Suganya, [11].

Harvest Index was founded to be highest in I3 regimes. The observation proved that difference nutrient management at different irrigation treatments i.e., (I3) produced highest harvest index (26.04%) followed by I2 (25.98%). Irrespective of irrigation levels, highest harvest index was calculated in N3 (25.74%) followed by N4 (25.20%). There is no significant difference among the treatment combination on harvest index. Higher yield obtained in increased irrigation are associated with higher harvest index found by Lin et al. [12].

3.4.1 Oil content

Oilcontentunderdifferentirrigationlevelsandnutrientmanagementarepresented in Table 8. I_3 resulted the statistically highest oil content of 51.44% and lowest oil content was found in I_1 (46.05%). Among the different nutrient management, in 100% RDF + 2 t/ha FYM + Jeevamrut @250 l/ha (N_3) found the highest oil content 50.04%(Table8). There is no significant difference among the treatment combination on oil content. Oil content differences among the irrigation levels may be due to water stress was also reported by Boydak et al. [13]. Increased oil content and oil yield may be due to application of nitrogen was also reported by Das and Das, [14].

3.5 Water Use Effiency

Crop water production functions describe the relationship of seed yield (Y) response to varying levels of water input and can be useful for various water management applications. Improving agricultural water use efficiency (WUE)isessential because of the

Table 5. Effects of irrigation and nutrient management on seed yield (kgha^{-1}), haulm yield (kg ha^{-1}) and harvest index (%) of summer sesame

Treatments	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)
I_1(2irrigationsat21and63days after sowing)	597.33	1775.19	25.18
I_2(2irrigationsat21and42days after sowing)	629.84	1794.27	25.98
I_3(3irrigationsat21,42and63daysaftersowing)	643.49	1828.13	26.04
SEm(±)	3.84	7.42	0.04
CD(0.05)	15.03	29.45	0.15
$N_1$100%RDF	591.94	1786.71	24.89
N_2(100% RDF+ 2 t/ha FYM)	617.08	1837.85	25.14
N_3(100%RDF+2 t/haFYM+ jeevamrut@250l/ha)	652.21	1882.07	25.74
N_4(75%RDF+2 t/haFYM + jeevamrut@250l/ha)	632.99	1878.82	25.20
SEm(±)	6.16	6.46	0.15
CD(0.05)	24.66	25.30	0.56

Table 6. Interaction effects of irrigation and nutrient management on seed yield(kgha^{-1}) on summer sesame

Irrigation	Nutrient management				Mean
	N_1	N_2	N_3	N_4	
I_1	570.00	586.7	625.6	607.1	597.34
I_2	598.96	628.1	654.6	637.7	629.85
I_3	606.88	636.5	676.5	654.2	643.49
Mean	591.9	617.1	652.2	633.0	

CD (P=0.05) Irrigation at the same nutrient management = 28.7Nutrientmanagementat same irrigation =24.2

Table 7. Interaction effects of irrigation and nutrient management on haulm yield (kg ha^{-1}) of summer sesame

Irrigation	Nutrient management				Mean
	N_1	N_2	N_3	N_4	
I_1	1732.00	1752.1	18208	1795.8	1775.19
I_2	1808.33	1880.2	1919.8	1903.1	1877.87
I_3	1819.79	1881.3	1930.6	1912.5	1886.04
Mean	1786.7	1837.8	1890.4	1870.5	

CD (P=0.05)

Irrigation at the same nutrient management=22.7, Nutrient management at same irrigation =9.5

Table 8. Effects of irrigation and nutrient management on oil content (%) of summer sesame

Treatments	Oil content (%)
I_1(2irrigationsat21and63daysafter sowing)	46.05
I_2(2irrigationsat21and42daysafter sowing)	47.99
I_3(3irrigationsat21,42and63daysaftersowing)	51.44
SEm(±)	0.5
CD(0.05)	2.04
N1 (100% RDF)	46.69
N2 (100% RDF+ 2 t/ha FYM)	48.01
N3 (100% RDF + 2 t/ha FYM jeevamrut@250l/ha)	50.04
N4 (75% RDF + 2 t/ha FYM + jeevamrut@250 l/ha)	49.24
SEm (±)	0.8
CD (0.05)	3.1

demand for increased grain production in India. The results revealed significant difference in seed yield due to the different water management treatments (Fig. 1). The lowest WUE was recorded for I_3N_1 (2.02 kg ha^{-1} mm^{-1}). Because, there was not much yield increment with the increase application of water. Treatment I_2N_3 produced highest WUE of 2.72 kg ha^{-1} mm^{-1} followed by I_2N_4 (2.65 kgha^{-1}mm^{-1}).

Research studies show that the practice of limiting water applications to drought-sensitive growth stages aims at maximizing water productivity and stabilizing,ratherthan maximizing, yields which is supported by S. Geerts and D. Raes, [15]. Ucan, [16] suggested that the WUE increases with irrigation amount, andwater-saving techniques such as deficit level have been improved water use efficiency (WUE) with minimum yield reduction. Thesametrend was observedin this present study. The increase or decrease in seed yield due to different nutrient management practices in summer sesame commensurate with the corresponding water use by the crop resulting in similar trend in water use efficiency of the crop to its consumptive use of water. This is also established by Dutta et al. [8].

3.6 Nutrient Uptake

3.6.1 Nitrogen

Total nitrogen content (%) in seed and haulm was obtained to be highest in I_3treatment. The observation proved that I_3 produced highest nitrogen content in seed (3.34%) and in haulm (1.03%) whereas, in I_1 found lowest nitrogen content (2.91%) followed by I_2 treatment (2.91%).

Total nitrogen content was found to be highest in N_3treatment. The observation proved that (N_3) produced highest nitrogen content (3.15%) whereas in N_1lowestnitrogen content (2.97%) observed (Table 9).

Likewise, nitrogen content, total nitrogen uptake (kg ha^{-1}) by seed and haulm was observed to be highest in I_3 treatment. The observation proved that I_3 produced highest nitrogen uptake by seed(21.51kgha^{-1}) and by haulm(19.34kgha^{-1}) whereas, I_1 showed the lowest nitrogen uptake by seed (17.34kg ha^{-1}) and by haulm (17.62 kgha^{-1}). Total nitrogen uptake was found to be highest in N_3 treatment. The observation proved that 100%RDF+2t/haFYM+Jeevamrut@250l/ha produced highest nitrogen uptake by seed (20.56 kg ha^{-1}) and by haulm (19.29 kg ha^{-1}) whereas, (N_1) produced lowest nitrogen uptake by seed (17.57 kg ha^{-1}) and by haulm (17.45 kg ha^{-1}) (Table 10). An excessive N rate or an inadequate amount of N application could increase N content in seeds. Our result is also similar with the finding of Chamorro et al. [17].

3.6.2 Phosphorus

Total phosphorus content (%) in seed and haulm was analyzed and presented inTabl 11. It was observed that 3 irrigations at 21, 42 and 63 days after sowing showed highest phosphorus content (%) in seed (2.25%) and in haulm (0.27%) where as in I_1 found lowest phosphorus content in seed (2.08%) and in haulm (0.22%). Total phosphorus content (%) was found to be highest in N_3 treatment. The observation proved that 100%RDF+2t/ha FYM+ Jeevamrut@250l/ha produced highest phosphorus content in seed (2.17%) and in haulm (0.25%) The lowest phosphorus content was found in seed (2.08%) and in haulm (0.22%) in N_1.

Table 11 represented the total phosphorus uptake (kg ha^{-1}) by seed and haulm.The highest phosphorus uptake by seed (14.46 kg ha^{-1}) and by haulm (5.00 kg ha^{-1})whereas, (I_1) produced lowest phosphorus uptake by seed (12.40 kg ha^{-1}) and by haulm(3.86kgha^{-1}). Total phosphorus content was found highest in100%RDF+2 t/haFYM+Jeevamrut@250l/ha application in both seed (10.12kg ha^{-1}) and haulm(2.95kgha^{-1}). The increases with irrigation frequency lead to higher phosphorus uptake due to the higher average moisture content in root zone of the crop. This result is in concurrent with Xu et al. [18].

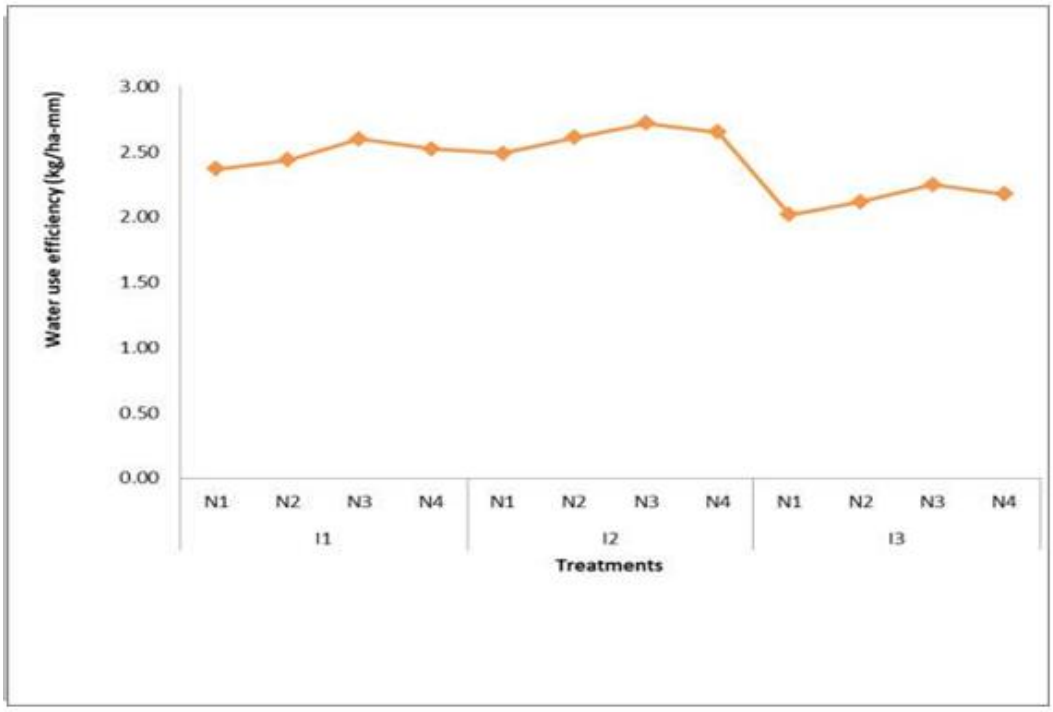

Fig. 1. Effects of irrigation and nutrient management on water use efficiency (kg ha-1 mm-1) of summer sesame

Table 9. Effects of irrigation and nutrient management on NPK content (%) in seed and haulm of summer sesame

	NPK content in seed			NPK content in haulm		
Treatments	**N content (%)**	**P content (%)**	**K content (%)**	**N content (%)**	**P content (%)**	**K content (%)**
I_1(2 irrigationsat 21and 63daysaftersowing)	2.91	2.08	0.88	0.99	0.22	1.14
I_2(2 irrigationsat 21and 42daysaftersowing)	2.91	2.07	0.88	0.98	0.22	1.14
I_3(3 irrigations at 21, 42and63daysaftersowing)	3.34	2.25	0.94	1.03	0.27	1.18
SEm(±)	0.04	0.02	0.02	0.01	0.02	0.01
CD(0.05)	0.12	0.06	0.06	0.02	0.05	0.02
N_1(100%RDF)	2.97	2.08	0.88	0.98	0.22	1.13
N_2(100% RDF+ 2t/ha FYM)	3.11	2.13	0.91	1.01	0.24	1.16
N_3(100%RDF+2 t/ha FYM+jeevamrut@250l/ha)	3.15	2.17	0.92	1.02	0.25	1.17
N_4(75%RDF+2 t/ha FYM+jeevamrut@250l/ha)	2.98	2.15	0.89	0.99	0.23	1.15
SEm(±)	0.05	0.03	0.02	0	0	0.01
CD(0.05)	0.15	0.9	0.05	0.01	0.01	0.02

Table 10. Effects of irrigation and nutrient management on NPK uptake(kgha^{-1}) by seed and haulm on summer sesame

	NPK uptake by seed			NPK uptake by haulm		
Treatments	**N Uptake (kg ha-1)**	**P Uptake (kg ha-1)**	**K uptake (kg ha-1)**	**N uptake (kg ha-1)**	**P uptake (kg ha-1)**	**K uptake (kg ha-1)**
I_1(2irrigationsat21and63daysaftersowing)	17.34	12.40	5.27	17.62	3.86	20.15
I_2(2irrigationsat21and42 daysafter sowing)	18.35	13.06	5.56	18.41	4.09	21.41
I_3(3irrigationsat21,42and63daysaftersowing)	21.51	14.46	6.04	19.34	5.00	22.31
SEm(±)	0.6	0.4	0.3	0.4	0.2	0.3
CD(0.05)	1.8	1.3	1	1.1	0.5	0.8
N_1(100%RDF)	17.57	12.30	5.21	17.45	3.88	20.14
N_2(100% RDF+ 2t/ha FYM)	19.21	13.13	5.62	18.50	4.42	21.26
N_3(100%RDF+2t/haFYM+jeevamrut@250l/ha)	20.56	14.15	6.03	19.29	4.67	22.19
N_4(75%RDF+2 t/ha FYM+jeevamrut@250l/ha)	18.92	13.64	5.64	18.59	4.31	21.58
SEm(±)	0.4	0.3	0.1	0.4	0.2	0.2
CD(0.05)	1.2	0.9	0.2	1.1	0.5	0.6

3.6.3 Potassium

Analyzed data of seed and haulm showed highest potassium content in I_3(0.94%) and (1.18 %). Irrespective of irrigation levels, N_3 (0.92%) in seed and (1.17%) in haulm found significantly highest potassium content. Potassium uptake by both seed (6.04 kg ha^{-1}) and haulm (22.31 kg ha^{-1}) found highest in I_3.100%RDF+2t/ha FYM+Jeevamrut@250l/ha showed highest potassium uptake by seed (6.03kgha^{-1}) and haulm (22.19kgha^{-1}) (Table 11). Uptake of N, P and K was the highest when the crop was irrigated with appropriate quantity water. The uptake pattern mostly followed the biomass yield trend due to different irrigation regimes, [8]. Uptake of nutrients by the plants was more efficient with the integrated use of inorganic and organic fertilization than that of using all organic sources alone. Beneficial effects of FYM have also been advocated by Deshmukh [19], Mishra [20] and Maravi [21].

3.7 Costo cultivation

The cost of cultivation, gross return, net return and benefit:cost ratio is presented in Table 11. Highest net return (Rs.19966.00 /-) as well as benefit cost ratio (1.68) calculated in (I_3N_3). Though the treatment I_2N_3 found same benefit cost ratio (1.68) but the second highest net return (Rs.19269.00 /-) obtained from this treatment. The lowest net return (Rs.15251.00/-) as well as benefit cost ratio (1.55) calculated in treatment I_1N_2.

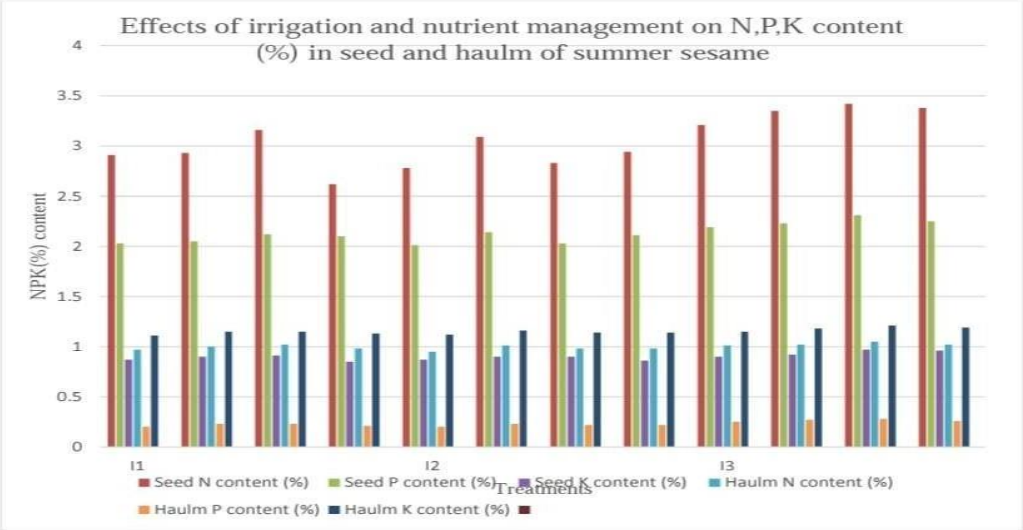

Fig. 2. Effects of irrigation and nutrient management on NPK content (%) of summer sesame

Table 11. Cost of cultivation of summer sesame influenced by irrigation and nutrient management

Treatments	Cost of cultivation (Rs./-)	Gross return (Rs./-)	Net return (Rs./-)	B:C ratio
I_1N_1	26175.00	41610.00	15435.00	1.59
I_1N_2	27575.00	42826.00	15251.00	1.55
I_1N_3	28515.00	45667.00	17152.00	1.60
I_1N_4	27895.00	44317.00	16422.00	1.59
I_2N_1	26175.00	43723.00	17548.00	1.67
I_2N_2	27575.00	45853.00	18278.00	1.66
I_2N_3	28515.00	47784.00	19269.00	1.68
I_2N_4	27895.00	46552.00	18657.00	1.67
I_3N_1	27075.00	44301.00	17226.00	1.64
I_3N_2	28475.00	46461.00	17986.00	1.63
I_3N_3	29415.00	49381.00	19966.00	1.68
I_3N_4	28795.00	47754.00	18959.00	1.66

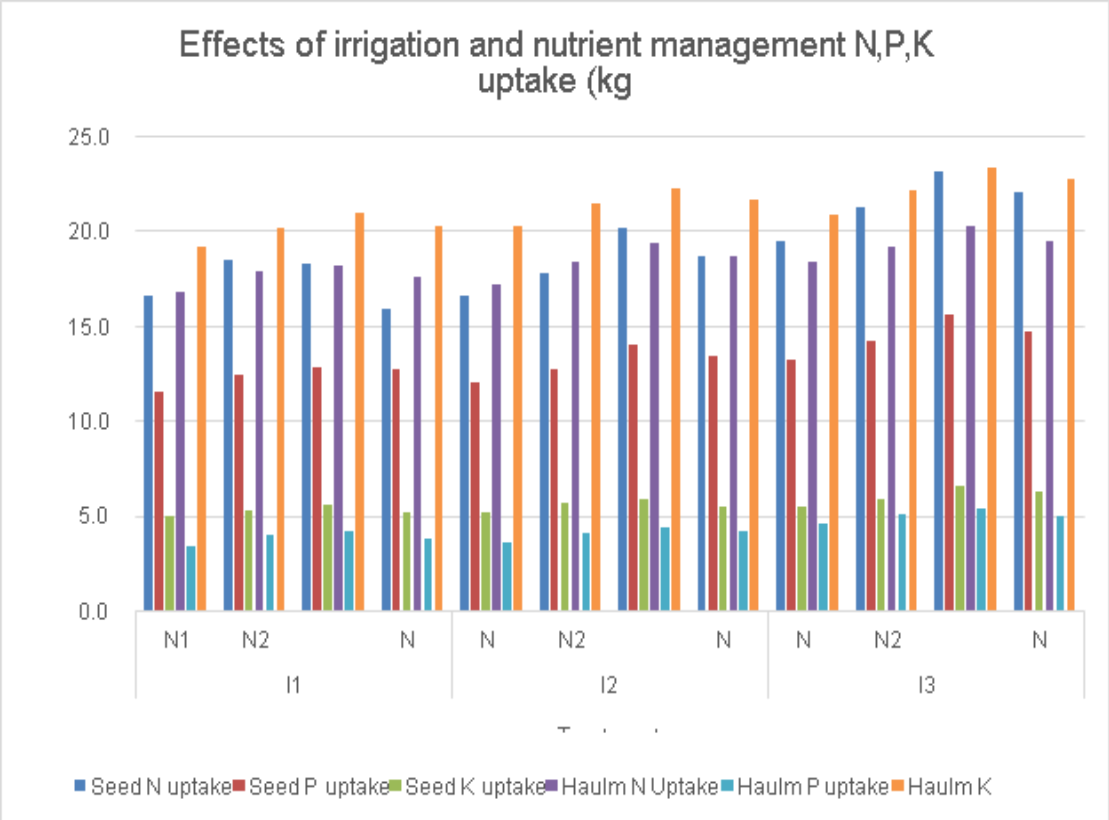

Fig. 3. Effects of irrigation and nutrient management on NPK uptake (kgha^{-1}) of summer sesame

4. CONCLUSION

From the experiment, it is concluded that the application of 2 irrigations at 21 and 42 days after sowing produced significantly higher yield (629.84 kg ha-1) compared to highest in 3 irrigations at 21, 42 and 63 days after sowing (643.49 kg ha-1). 75% RDF, 2 t/ha FYM and Jeevamrut @250 l/ha recorded significantly higher yield (632.99 kg ha-1) comparison with 100% RDF, 2 t/ha FYM and Jeevamrut @250 l/ha (652.21 kg ha-1). It is further infrared that the summer sesame recorded significantly higher seed yield (676.5 kg ha-1), net return (Rs. 19966.00/- /ha) and benefit: cost ratio (1.68) in 3 irrigations at 21, 42 and 63 days after sowing with 100% RDF, 2 t/ha FYM and Jeevamrut @250 l/ha application. However, significantly no yield loss occurred in 2 irrigations at 21 and 42 days after sowing with 75% RDF, 2 t/ha FYM and Jeevamrut @250 l/ha application (654.2 kg ha-1) and highest water use efficiency calculated (2.72 kg ha-1 mm-1) in 2 irrigations at 21 and 42 days after sowing with 100% RDF, 2 t/ha FYM and Jeevamrut @250 l/ha application.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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