Comparative study of irrigation and nitrogen management on *summer* sesame (*Sesamumindicum* L.)

ABSTRACT

Aim: The aim of the experiment is to know the effect of irrigation and nitrogen management on growth, yield attributes, yield, economics and WUE of *summer* sesame.

Study design: The experiment was laid out in split-plot design.

Place and Duration of Study: Research Farm of Agricultural Research Station, Brinjhagiri, Chhatabar of Faculty of Agricultural Sciences, Siksha O Anusandhan (Deemed to be University), Bhubaneswar (Odisha), during *summer* season of 2024.

Methodology: Three levels of irrigation (I_1 -3 irrigations at branching, flowering and capsule development stage, I_2 -2 irrigations at branching and flowering stage and I_3 -2 irrigations at branching and capsule development stage) as main-plot treatments and four nutrient management levels (N_1 -STBR- 100% N through inorganic, N_2 -75% N through inorganic + 25% N through FYM, N_3 -75% N through inorganic + 25% N through vermicompost and N_4 -50% N through inorganic + 25% N through FYM+ 25% N through vermicompost) as sub-plot treatments replicated thrice. The net plot size was 4m 3m.

Results:I_1resulted the highest seed yield (795.1kgha^{-1}) and stover yield (2057.1 kgha^{-1}). N_1 produced highest seed yield (818.9 kgha^{-1}) and stover yield (2101.4 kgha^{-1}). Highest net return (Rs.35894.00 /-) as well as return per rupee investment (1.83) was obtained in I_1N_1. The highest WUE (4.26 kgha^{-1}mm^{-1}) was calculated in I_2N_1.

Conclusion: Three irrigations at branching, flowering and capsule development stage and 50% N through inorganic + 25% N through FYM + 25% N through vermicompost can be recommended to achieve higher seed yield, highest oil content and oil yield.

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Key words: *Sesame, Irrigation, Farm Yard Manure, Vermicompost, Integrated Nutrient Management, Water Use Efficiency, Yield*

1. INTRODUCTION

Oilseeds play a vital role in agricultural and industrial economics in world. Oilseeds are the main source of fats and protein particularly for vegetarians. Sesame (*Sesamumindicum* L., 2n = 26), an ancient oilseed crop that belongs to the Pedaliaceae family, is widely cultivated in Africa and Asia [32,27,29]. It commonly cultivate in tropical and subtropical areas. Because of its excellent stability, drought resilience and ease of extraction, it was a prominent oilseed crop in antiquity. Sesame is traditionally categorized as a health food in Asian countries [17]. Sesame seed cake contains 32% crude protein and 8–10% oil, making it an essential feed for livestock, poultry, and small ruminants [11]. The crop thrives best on moderately fertile, well-drained soils with a pH ranging from 5.5 to 8.0 and is sensitive to salinity. Despite its global presence, the sesame industry still has challenges, like yield instability, susceptibility to biotic and abiotic stresses, and limited technological advancements in cultivation practices. Sesame yield is low due to the lack of high-yielding and adapted varieties, vulnerability to capsule shattering, indeterminate growth habits, as well as biotic and abiotic stresses [12, 20]. It is mostly grown under rainfed conditions of arid and semi-arid areas where mild-to-severe water deficit stress is experienced. Sesame productivity is limited in those areas by drought and salinity. It is sensitive to drought mainly at the vegetative stages [3] in all of its growing regions and has low production potential in semiarid regions due to drought stress. Grain yield as well as oil yield and quality are decreased depending on genotypes and drought intensity. Sesame requires regular rainfall or proper irrigation. However, extreme conditions like flooding, drought, and waterlogging can negatively affect growth and seed yield, underscoring the need for well-managed water levels [30]. Positive effects of optimal irrigation practices during vegetative, flowering, and fruiting stages on sesame yield have been reported [6]. The critical stages for water application since this crop was predominantly cultivated in post rainy or summer season with restricted water accessibility and yield decrease was essentially because of water deficiency particularly at moisture sensitive stages showing the significance of irrigation on plant growth and development [5].

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Nutrient deficiency and imbalanced fertilizers use are one of the important factors for low yield of sesame. The key component of theINM is to decrease the enormous use of chemical fertilizers and accelerating a balance between fertilizer inputs and crop nutrient requirement, optimizing the level of yield, maximizing the profitability, and subsequently reducing the environmental pollution [22]. Yield potential of the crop can be maximized by balanced and efficient use of organic and inorganic sources of nutrients [14]. Efficient management of organic and inorganic source is prerequisite for achieving continuous production of crops in an economically and sustainable manner. Organic matter forms a very important source of plant nutrients whereas organic manures are used to supply both macro and micronutrients and sustain amount of humic substances particularly humic and fulvic acid that helps to maintain soil pH. Thus, for maintenance of the soil fertility, productivity and soil health with the FYM, compost and biofertilizers can't replace chemical fertilizers but certainly are capable of reducing their inputs [8]. Organic manures like farmyard manure, vermicompost and poultry manure are good source of nutrients required by plants for quality produce. Appropriate and conjunctive use of application of suitable nutrients through organic and inorganic solely or in combination can provide the solutions to the problems such as increase price of inorganic fertilizers and deterioration effect of soil fertility and productivity [24]. Integrated use of nutrient is very essential approach, which not only

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sustains high crop production over the years but also improves soil health and ensures a safer environment. Nitrogen is essential for vegetative and reproductive growth, being a major structural constituent of cell. The application of N significantly increased the dry matter accumulation of root and shoot in crop at different growth stages [15]. Keeping these views in mind an experiment conducted with the objective to know the effect of irrigation and nitrogen management on growth, yield attributes, yield, economics and WUE of *summer* sesame.

2. MATERIALS AND METHOD

An experiment was carried out at Research Farm of Agricultural Research Station, Brinjhagiri, Chhatabar of Faculty of Agricultural Sciences, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar (Odisha) during *summer* season of 2024. The location is situated in the South east coastal plain Zone of India. The field where the experiment was conducted is located at Latitude is 20.46^{o}N and Longitude 85.67^o E. The soil was sandy loam in texture, slightly acidic in reaction (pH **5.7**), medium in organic carbon 0.42% (Walkley and Black, 1934 and Muhr*et al*.,1965), with medium available nitrogen 263.7 kgha^{-1} (Alkaline permanganate method, Jackson, 1973), medium in available phosphorus 18.4 kgha^{-1} (Olsen's method, Olsen *et al.,* 1954)) and medium available potassium 136.7 kgha^{-1} (Flame photometer Method, Muhr*et al*.1965) (Table 1). The experimental sesame variety "Prachi (ORM-17)" that was used in the study is a black-seeded variety with duration of 85–95 days. The net plot size was 4.0 m × 3.0 m. The experiment was laid out in a split plot design having three levels of irrigation (I_1 -3 irrigations at branching, flowering and capsule development stage, I_2 -2 irrigations at branching and flowering stage and I_3 -2 irrigations at branching and capsule development stage) as main-plot treatments and four nutrient management levels (N_1 -STBR- 100% N through inorganic, N_2 -75% N through inorganic + 25% N through FYM, N_3 -75% N through inorganic + 25% N through vermicompost and N_4 -50% N through inorganic + 25% N through FYM+ 25% N through vermicompost) as sub-plot treatments with three replications. A considerable amount of rainfall (75.1mm) occurred during cropping season (Figure 1). A common pre-sowing irrigation was given to all plots and later on irrigation was given as per treatments. Irrigation at branching, flowering and capsule development stage was given at a depth of 6cm using Area- Velocity method. The recommended dose of fertilizer was 40: 20: 20 (N, P_2O_5, K_2O) kgha^{-1}. Organic sources of nitrogen were applied a day before sowing. The N, P and K were supplied through urea, single super phosphate and mutate of potash, respectively. Half of N along with full dose of P and K were applied as basal and mixed with the soil of the individual plots. The rest of the N dose (half of recommendation) was top dressed at branching stage according to the treatment. The biometric data like, plant height (cm), dry matter accumulation (gm^{-2}) and number of branches plant^{-1} and yield related data like, number of capsules plant^{-1}, test weight (g), seed yield (kgha^{-1}) and stover yield (kgha^{-1}) was taken during maturity period. Harvest index, water use efficiency (kgha^{-1}mm^{-1}) and economics of cultivation were calculated. The experimental data recorded were subjected to statistical analysis by the analysis of variance method (Gomex and Gomex, 1984). Fisher's 'F' test at probability level 0.05 tested the significance of different sources of variations. For the determination of critical difference at 5 % level of significance, Fisher and Yate's tables were consulted. The value of standard error of mean (Sem (±)) and the least significant difference (CD) to compare

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Table 1: Soil physico-chemical properties of experimental soil

Sl. No	Properties	Value	Method used
1.	Mechanical composition Sand (%) Silt (%) Clay (%)	 72.8%, 21.2% 6%	International pipette method (Jackson, 1973)
2.	Soil texture	Sandy loam soil	USDA system (Brady, 1974)
3.	pH	5.7	(Jackson, 1973)
4.	Electrical conductivity (ds m^{-1})	7.33	(Jackson, 1973)
5.	Organic carbon (%)	0.42	Walkley and Black method (Jackson, 1973)
6.	Available nitrogen (kg/ha)	263.7	Alkaline permanganate method (Jackson, 1973)
7.	Available phosphorus (kg/ha)	18.4	Olsen's method (Olsen *et al.,* 1954)
8.	Available potassium (kg/ha)	136.7	Flame photometric method (Jackson, 1973)

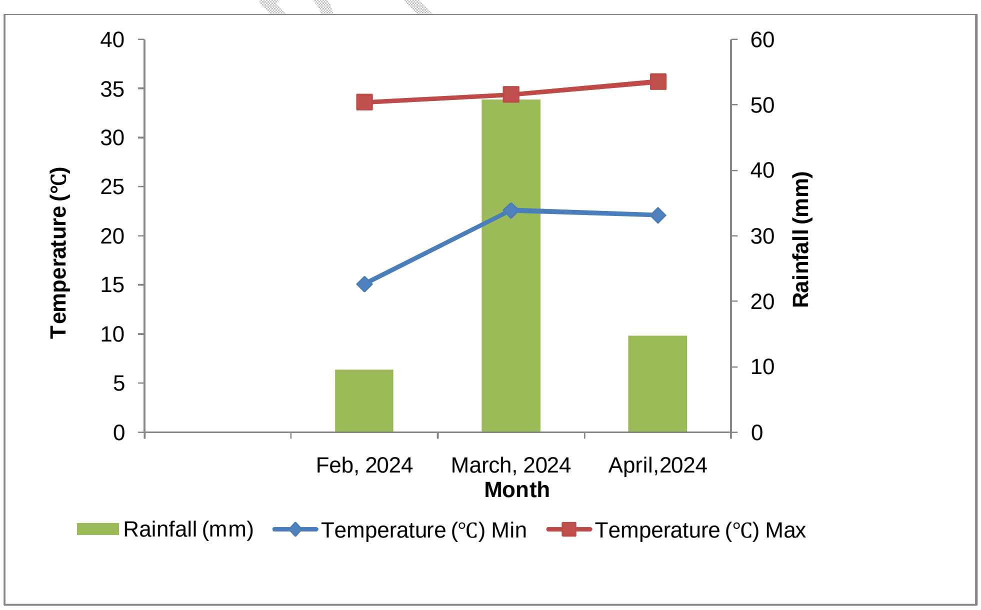

Fig. 1: Monthly, Maximum and Minimum temperature, Rainfall during experimental period

3. RESULTS AND DISCUSSION

3.1 Effect on growth parameters

Observations from the entire study proved that, the I_1 regime (3 irrigations at branching, flowering, and capsule development stages) produced the tallest plant (83.1 cm), the maximum amount of dry matter accumulation (402.6 gm^{-2}) and the highest number of branches $plant^{-1}$ (4.2) followed by the I_2 regime(2 irrigations at branching and flowering stages) (82.4 cm, 387.8 gm^{-2} and 4.0 respectively). Increase in dry matter yield under I_1 might be due to the fact that crop might have received right quantity of irrigation water at right crop growth stage. This result is in close agreement with the results obtained by [19,4].

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Irrespective of irrigation management, N_1 (STBR-100% N through inorganic) attained the tallest plant height (83.6cm) followed by N_4 (50% N through inorganic + 25% N through FYM + 25% N through vermicompost) (82.6cm).Whereas, at maturity, N_4 (50% N through inorganic + 25% N through FYM + 25% N through vermicompost) produced the highest amount of dry matter (403.1 gm^{-2}) and the highest number of branches $plant^{-1}$ (4.3) followed by N_1 (STBR-100% N through inorganic) 394.8 gm^{-2} and 4.1 respectively. This might be due to the effect of organic and inorganic fertilizers combination to increasing growth attributes and production of more dry matter [23]. Nitrogen application significantly affects the dry matter accumulation crop at different growth stages [15] (Table 2).

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3.2 Effect on yield and yield attributing characters

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The highest number of capsules $plant^{-1}$ (41.2), number of seeds per capsule (57.7) was observed in I_1 (3 irrigations at branching, flowering and capsule development stage) and is statistically at par with I_2 (2 irrigations at branching and flowering stage) 40.6 and 55.9 respectively. Test weight was counted to be highest in I_1 regime (2.66g) and lowest in I_2 regime (2.41g). Among different nitrogen management, the highest number of capsules $plant^{-1}$ (43.0), number of seeds $capsule^{-1}$ (58.8) was observed in N_1 (STBR- 100% N through inorganic) and is at par with N_4 (50% N through inorganic + 25% N through FYM+ 25% N through vermicompost) 42.1 and 55.9 respectively. Maximum test weight (2.66g) was obtained in N_4 (50% N through inorganic + 25% N through FYM+ 25% N through vermicompost) (Table 2). Significantly higher number of seed-bearing parts $plants^{-1}$ was with the application of nitrogen fertilizer and vermicompost in an integrated pattern, which might have helped to supply sufficient nutrients throughout the growth period [18]. The application of organic sources resulted in a significant and maximum number of seeds $plant^{-1}$, potentially improving the overall growth of the crop at a lower cost. Thus, greater availability of metabolic activity and nutrients to develop reproductive structures seems to have resulted in an increased number of seeds $plant^{-1}$ [26,2].

Treatments	Plant height (cm)	Dry matter accumulation (gm^{-2})	Number of branches plant $^{-1}$	Number of capsules plant^{-1}	Number of seeds capsule^{-1}	Test weight (g)

Table 2: Effect of irrigation and nitrogen management on plant height, number of branches plant^{-1}, number of capsules plant^{-1}, number of seeds capsule^{-1} and test weight (g) at maturity on *summer*sesame

I_1 (3 irrigations at branching, flowering and capsule development stage)	83.1	402.6	4.2	41.2	57.7	2.66
I_2 (2 irrigations at branching and flowering stage)	82.4	387.8	4.0	40.6	55.9	2.41
I_3(2 irrigations at branching and capsule development stage)	78.5	363.3	3.8	38.9	50.9	2.57
SEm (±)	**0.4**	**4.3**	**0.1**	**0.44**	**1.3**	**0.05**
CD (0.05)	**1.6**	**16.9**	**0.5**	**1.8**	**5.1**	**0.20**
N_1 (STBR- 100% N through inorganic)	83.6	394.8	4.1	43.0	58.8	2.57
N_2(75% N through inorganic + 25% N through FYM)	79.1	366.4	3.9	37.1	50.4	2.46
N_3(75% N through inorganic + 25% N through vermicompost)	80.1	373.8	3.9	38.7	54.3	2.49
N_4 (50% N through inorganic + 25% N through FYM+ 25% N through vermicompost)	82.6	403.1	4.3	42.1	55.9	2.66
SEm (±)	**0.6**	**4.7**	**0.1**	**0.5**	**1.0**	**0.1**
CD (0.05)	**2.3**	**18.5**	**0.6**	**2.0**	**3.8**	**0.4**

Three irrigations at branching, flowering and capsule development stage (I_1) resulted the highest seed yield (795.1kgha^{-1}), stover yield (2057.1 kgha^{-1}) and harvest index (0.28) followed by I_2 (2 irrigations at branching and flowering stage) 763.3 kgha^{-1}, 2012.7 kgha^{-1} and 0.28 respectively. The maximum amount of seed yield in 3 irrigations at branching, flowering and capsule development stage (I_1) may be due to producing the maximum number of capsules per plant on account of the higher availability of water. Higher seed yield of sesame with optimum irrigation schedule [1]. Water deficiency during reproductive stage especially during capsule formation stage showed drastic reduction in seed yield (Ekom*et al*., 2019)[9].Irrespective of irrigation levels, STBR- 100% N through inorganic (N_1) produced highest seed yield (818.9 kgha^{-1}), stover yield (2101.4 kgha^{-1}) and harvest index (0.28), followed by N_4 (50% N through inorganic + 25% N through FYM+ 25% N through vermicompost), 791.5 kgha^{-1}, 2067.0 kgha^{-1} and 0.28 respectively. The elevated yield due to integrated application of synthetic fertilizer and organic manures could be attributed to more exploitation of crop genetic potential for vegetative and reproductive growth and sustained nutrient supply [7,24]. Combined application of organic manures and chemical fertilizers resulted in better consumption of applied nutrients through enhanced micro environmental conditions and the activities of soil microorganisms involved in nutrient transformation and fixation [31,13] (Table 3).

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3.3 Oil content and oil yield

Three irrigations at branching, flowering and capsule development stage (I_1) resulted in statistically highest oil content (47.2%) and oil yield (371.1kgha^{-1}). The lowest oil content was found in 2 irrigations at branching and capsule development stage (I_3)(44.4%) and oil yield (306.5 kgha^{-1}). Among the different nitrogen management, it was found out that N_4 with 50% N through inorganic + 25% N through FYM+ 25% N through vermicompost, gave the highest oil content (48.1%) and oil yield (381.0 kgha^{-1}). The increase in oil content with application of

FYM, vermicompost and chemical fertilizers might be due to enhanced availability of sulphur which involved in conversion of primary fatty acid metabolites to the end products of fatty acid [16, 21] (Table 3).

Table 3: Effect of irrigation and nitrogen management on seed yield ($kgha^{-1}$), stover yield ($kgha^{-1}$), harvest index (%), oil content (%) and oil yield ($kgha^{-1}$) on summer sesame

Treatments	Seed yield ($kgha^{-1}$)	Stover yield ($kgha^{-1}$)	Harvest index	Oil content (%)	Oil yield ($kgha^{-1}$)
I_1 (3 irrigations at branching, flowering and capsule development stage)	795.1	2057.1	0.28	47.2	371.1
I_2 (2 irrigations at branching and flowering stage)	763.3	2012.7	0.28	46.5	350.4
I_3(2 irrigations at branching and capsule development stage)	698.8	1990.4	0.26	44.4	306.5
SEm (±)	**8.6**	**23.6**	**0.001**	**0.3**	**7.7**
CD (0.05)	**34.6**	**92.8**	**0.004**	**1.2**	**30.3**
N_1 (STBR- 100% N through inorganic)	818.9	2101.4	0.28	46.0	358.3
N_2(75% N through inorganic + 25% N through FYM)	680.5	1921.3	0.26	44.6	304.2
N_3(75% N through inorganic + 25% N through vermicompost)	718.8	1990.4	0.27	45.5	327.2
N_4 (50% N through inorganic + 25% N through FYM+ 25% N through vermicompost)	791.5	2067.0	0.28	48.1	381.0
SEm (±)	**8.8**	**10.8**	**0.001**	**0.5**	**9.5**
CD (0.05)	**34.2**	**42.5**	**0.003**	**2.1**	**37.2**

3.4 Water Use Efficiency

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) is essential because of the demand for increased grain production in India. The results revealed significant difference in seed yield due to the different water management treatments (Figure 1). The highest WUE (4.26 $kgha^{-1}mm^{-1}$) was calculated in I_2N_1 (2 irrigations at branching and flowering stage with STBR-100% N through inorganic). The second highest WUE (4.11 $kgha^{-1}mm^{-1}$) was calculated in I_2N_4 (2 irrigations at branching and flowering stage with 50% N through inorganic + 25% N through FYM+ 25% N through vermicompost). That may be due to a considerable less amount of water application without affecting crop yield. In case of I_1N_2 (3 irrigations at branching, flowering and capsule development stage with 75% N through inorganic + 25% N through FYM) produced the lowest WUE of 2.79 $kgha^{-1}mm^{-1}$. Because application of irrigation water was more whereas, seed yield obtained was lesser among all I_1 regimes.

Research studies show that the practice of limiting water applications to drought-sensitive growth stages aims at maximizing water productivity and stabilizing, rather than maximizing, yields [10]. Ucan [28] suggested that the WUE increases with irrigation amount, and water-saving techniques such as deficit level have been improved water use efficiency (WUE) with minimum yield reduction.

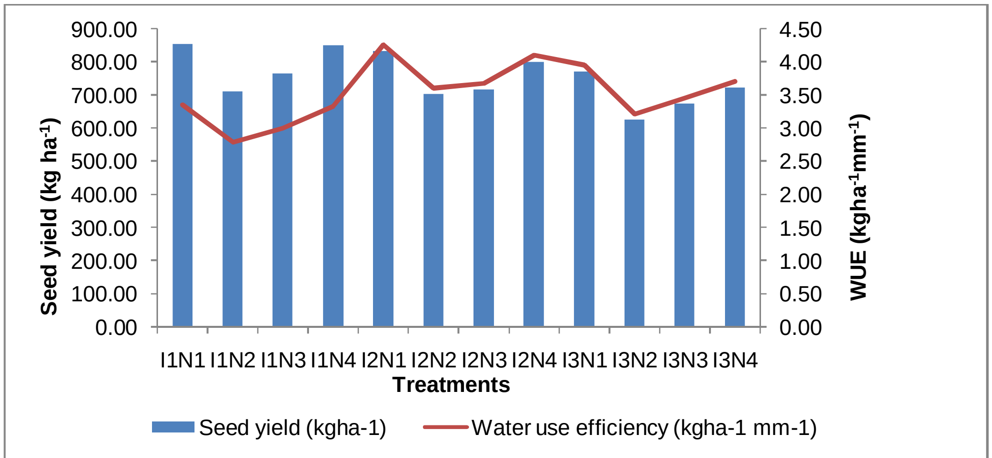

Fig. 2: Interaction effect of irrigation and nitrogen management on Water Use Efficiency (kgha^{-1}mm^{-1}) of *summer* sesame

3.5 Cost of cultivation

Highest net return (Rs.35894.00 /-) as well as return per rupee investment (1.83) was obtained in 3 irrigations at branching, flowering and capsule development stage with STBR- 100% N through inorganic (I_1N_1). The second highest net return (Rs.34804.00/-) was obtained in treatment with 2 irrigations at branching and flowering stage with STBR- 100% N through inorganic (I_2N_1). The lowest net return (Rs.12361.00/-) as well as return per rupee investment (1.25) calculated in treatment with 2 irrigations at branching and capsule development stage with 75% N through inorganic + 25% N through vermicompost (I_3N_3).

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Table 4 -Cost of cultivation of *summer* sesame influenced by irrigation and nitrogen management

Treatments	Cost of cultivation (Rs/-)	Gross return (Rs/-)	Net return (Rs/-)	Return per rupee investment
I_1N_1 (3 irrigations at branching, flowering and capsule development stage with STBR- 100% N through inorganic)	43246	79140	35894	1.83
I_1N_2 (3 irrigations at branching, flowering and capsule development stage with 75% N through inorganic + 25% N through FYM**)**	44872	65940	21067	1.47
I_1N_3 (3 irrigations at branching, flowering and capsule development stage with 75% N through inorganic + 25% N through vermicompost**)**	51072	70903	19830	1.39
I_1N_4 (3 irrigations at branching, flowering and capsule development stage with 50% N through inorganic + 25% N through FYM+ 25% N through vermicompost**)**	52699	78749	26050	1.50
I_2N_1 (2 irrigations at branching and flowering stage with	42246	77050	34804	1.82

STBR- 100% N through inorganic**)**				
I_2N_2 (2 irrigations at branching and flowering stage with 75% N through inorganic + 25% N through FYM**)**	43872	65168	21295	1.48
I_2N_3 (2 irrigations at branching and flowering stage with 75% N through inorganic + 25% N through vermicompost**)**	50072	66491	16418	1.33
I_2N_4 (2 irrigations at branching and flowering stage with 50% N through inorganic + 25% N through FYM+ 25% N through vermicompost**)**	51699	74239	22540	1.44
I_3N_1 (2 irrigations at branching and capsule development stage with STBR- 100% N through inorganic**)**	42246	71459	29213	1.69
I_3N_2 (2 irrigations at branching and capsule development stage with 75% N through inorganic + 25% N through FYM**)**	43872	58089	14216	1.32
I_3N_3 (2 irrigations at branching and capsule development stage with 75% N through inorganic + 25% N through vermicompost**)**	50072	62434	12361	1.25
I_3N_4 (2 irrigations at branching and capsule development stage with 50% N through inorganic + 25% N through FYM+ 25% N through vermicompost**)**	51699	67047	15348	1.30
SEm (±)	-	**51.7**	**28.1**	-
CD (0.05)	-	**205.2**	**112.6**	-

4. CONCLUSION

Three irrigations at branching, flowering and capsule development stage produced highest seed yield, oil content and oil yield. 50% N through inorganic + 25% N through FYM + 25% N through vermicompost can be recommended to achieve higher seed yield, highest oil content and oil yield. Application of 2 irrigations at branching and flowering stage with STBR- 100% N through inorganic treatment is economical as, it gives higher net return and return per rupee investment.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Comment [RK27]: Reference not found in text

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