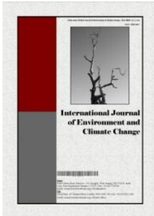

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# Effect of Deficit and Optimum Irrigation at Various Growth Stages on Yield Attributes, Yield and Economics of *Summer* Sesame

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***Authors' contributions***

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

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## ABSTRACT

**Aims:** Sesame is grown in the country since antiquity. Sesame has high nutritional benefits and is utilized in numerous cooking styles everywhere globally. Sesame is called as the queen of oilseeds for the reason of its top notch polyunsaturated stable fats that limit oxidative rancidity and contains high oil content (up to 60%). Sesame is cultivated in *summer* in the North Telangana in turmeric and rice fallows. Low productivity in sesame is primarily due to rainfed planting on sub-marginal and marginal lands with poor management and low investment. To solve the upcoming challenges and in view of the improving yield and acquire higher returns, precised water management strategies need to be formulated. Hence the present investigation is proposed to study the effect of deficit and optimum irrigation at various growth stages on yield and economics of sesame crop grown in *summer*.

**Study Design:** The experiment was laid out in a randomized complete block design.

**Methodology:** A field experiment was conducted at Agricultural college, Polasa, Jagtial district during *summer* 2021 to study the effects of water deficit and optimal irrigation at various growth

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stages on yield and economics of *summer* sesame. The study is conducted with eight deficit and optimum irrigation treatments ($T_1$ to $T_8$) and replicated thrice.
**Results:** The results of this experiment manifested that scheduling irrigation at vegetative, prebloom, flowering, capsule initiation and capsule filling stages ($T_8$) registered highest yield attributes, yield and economic parameters*viz*., no of capsules plant$^{-1}$ (45), capsule weight (0.32 g) and no of filled seeds capsule$^{-1}$ (55), seed yield (1150 kg ha$^{-1}$), stalk yield (1999 kg ha$^{-1}$), gross returns (128499 ₹ ha$^{-1}$), net returns (94391 ₹ ha$^{-1}$) and benefit cost ratio (2.76).

*Keywords: Deficit and optimum irrigation; Yield attributes; Yield; economics.*

## 1. INTRODUCTION

Oilseeds are among the major crops that are grown in the country apart from cereals. Oilseed crops are the important crops because of their high economic value and are acclimatized to grow in higher percent area of the globe. Oilseeds play a crucial role in the Indian economy, accounting for 5% of India's GDP and 10% of the value of agricultural commodities. In India, second largest agricultural commodity after cereals are oilseeds, accounting for approximately 13.5% of the country's total cropped area [1].

Sesame (*Sesamum indicum* L.) (2n=26) being included in the family Pedaliaceae and order Tubiflorae is native of Africa and one of the earliest domesticated plants of India. India is one of the significant exporters of sesame with an acreage of 14.19 lakh hectares, production of 6.89 lakh tons and productivity of 485 kg ha$^{-1}$ [2]. In Telangana, it has a planting area of 18,000 hectares, an annual output of 12,190 tonnes, and a productivity of 677 kg ha$^{-1}$ [2].

Sesame seed is frequently known as Til in India. It is likewise called as benniseed, benne, gingelly, gengelin, tila, and sim-sim or semsemin [3]. Sesame has high nutritional benefits and is utilized in numerous cooking styles everywhere in the world. Sesame is called as the queen of oilseeds for the reason of its top notch polyunsaturated stable fats that limit oxidative rancidity and contains high oil content (up to 60%). Sesame is a rich wellspring of nutritive and medicinal properties [4]. Sesame seed oil contains unsaturated fats (83-90%), protein (20%), traces of micronutrients (nutrients and minerals) and a lot of trademark lignin, (for example, sesamin, sesamol, sesamin and tocopherol) [5]. Roughly, 70% of overall sesame seed produced is prepared into oil and meal. The Sesame seeds or its powder or oil were utilized in different Indian dishes as enhancing specialist [6].

Sesame is mainly grown as a *summer* crop, *kharif* crop and as late-*rabi* crop. In Telangana, Sesame is mainly grown as *summer* crop in the turmeric and rice fallows with limited irrigation under well/canal irrigation. Irrigation water was found to be the most basic factor that restrict the development and yield of crops grown in summer. Due to insufficient water supply, the productivity of *summer* sesame in Northern Telangana Zone is low. Scheduling of limited water assets to increase the productivity of crops is the most pressing need. Application of irrigation at branching, flowering and capsule development stages increased yield crediting characters and yield of *summer* sesame [7,8]. Deficit water system is an approach which permits a crop to undergo some level of water deficit to diminish irrigation costs and possibly increment incomes. Irrigation and nutrients are the important agronomic inputs that boost the yield, quality and economics of *summer* sesame [9]. The prime objective of deficit irrigation is to elevate the productivity of a crop by eliminating the irrigations that have little impact on yield. It is therefore necessary to develop best water deficit irrigation strategy.

## 2. MATERIALS AND METHODS

The field attempt entitled "Effect of deficit and optimum irrigation at various growth stages on yield attributes, yield and economics of *summer* sesame" was executed during *summer* season, 2021 at Professor Jayashankar Telangana State Agricultural University, Agricultural college, College farm, Polasa, Jagtial. The experimental soil was sandy clay loam in texture, non-saline (0.31 dS m$^{-1}$) and slightly alkaline (7.99) in reaction. The available soil moisture (mm) in a depth of 0-60 cm was 91.57 mm. Fertility status of the experimental soil was low in organic carbon (0.50%) and available nitrogen (157.0 kg

$ha^{-1}$), high in available phosphorus (23.2 kg $ha^{-1}$) and potassium (297.0 kg $ha^{-1}$). Rainfall was not received during crop growth period.

The investigation was spread out in randomized complete block design with eight treatments repeated threefold. Treatments comprised of varied number of irrigations scheduled at different crop growth stages *i.e.,* vegetative, prebloom, flowering, capsule initiation and capsule filling stages. The treatments were $T_1$- 2 irrigations each at vegetative and flowering stages; $T_2$- 2 irrigations each at vegetative and capsule filling stages; $T_3$- 2 irrigations each at flowering and capsule filling stages; $T_4$- 3 irrigations each at vegetative, flowering and capsule filling stages; $T_5$- 3 irrigations each at vegetative, prebloom and capsule filling stages; $T_6$- 4 irrigations each at vegetative, prebloom, flowering and capsule filling stages; $T_7$- 4 irrigations each at vegetative, flowering, capsule initiation and capsule filling stages and $T_8$- 5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stages. In sesame cultivation, recommended fertilizer dose of 60: 20: 40 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$ was followed. These nutrients were applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. Complete dose of $P_2O_5$ was applied as basal dose. $K_2O$ was applied in 2 splits at basal and at flowering stage and nitrogen was applied in 3 equal splits at basal, vegetative and at flowering stages. The variety JCS 1020 (Jagtial Til-1) was sown on 3rd February, 2021 and harvested from 8th-10th May, 2021. Quantity of Irrigation water is measured with water meter. At harvest, yield attributes were measured. Seed and stalk yield were recorded. Economic parameters were worked out on hectare premise by considering prevailing market price of various inputs and existing labour wages during the experimental period. Data is statistically analyzed as illustrated by Panse and Sukhatme [10].

## 3. RESULTS AND DISCUSSION

### 3.1 Yield Attributes

The data on effect of deficit and optimum irrigation at various growth stages on yield attributes like no of capsules $plant^{-1}$, capsule weight and no of filled seeds $capsule^{-1}$ were presented in Table 1. The results of this experiment showed that scheduling 5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stages ($T_8$) recorded significantly higher number of capsules $plant^{-1}$ (45), capsule weight (0.32 g) and number of filled seeds $capsule^{-1}$ (55) followed by $T_7$, $T_6$, $T_4$, $T_5$, $T_3$ and $T_1$. Whereas treatment provided with 2 irrigations each at vegetative and capsule filling stages ($T_2$) showed lower values of all the aforementioned yield attributes.

Yield is a composite of number of capsules $plant^{-1}$, seeds $capsule^{-1}$ and seed weight and almost 85% of sesame yield variations were achieved by capsules $plant^{-1}$ [11]. Increasing number of irrigations increased the number of capsules $plant^{-1}$. Water stress at reproductive stage brought about an irreversible impact which could not be revoked during subsequent good soil moisture levels when the crucial processes of capsule development are still underway. The results obtained in the current investigation were supported by Puste et al. [12].

Capsule weight also increased with increasing number of irrigations. This was supported by Mila et al. [13] and Eltarabily et al. [14] in sunflower. Lower capsule weight in treatments subjected to deficit irrigation can be attributed to retarded growth and consequently a smaller number of capsules. Treatments devoid of irrigation at flowering stage ($T_2$ and $T_5$) showed reduced capsule weight due to deformed capsules. Higher number of filled seeds $capsule^{-1}$ with increasing number of irrigations might be due to higher number of capsules and effective translocation of photosynthates from source to sink in optimum irrigated treatments. The results obtained were in supported by Chauhan et al. [15] Mallick [16] and Mekonnen and Sintayehu, [8] in sesame and by Lovelli et al. [17] in safflower, Istanbulluoglu et al. [18] in rapeseed, Langerhoodi et al. [19] and Eltarabily et al. in sunflower and Rathore et al. [20] in mustard.

### 3.2 Yield

Seed and stalk yield of *summer* sesame as influenced by deficit and optimum irrigation at various growth stages were presented in Table 1 and Fig. 1. Highest seed yield (1150 kg $ha^{-1}$) was acquired by providing 5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stages ($T_8$). Higher seed yield of sesame with optimum irrigation schedule was supported by Hailu *et al*. [21], Abdelraouf and Anter, [22] This might be due to enhanced performance of all yield contributing characters because of uninterrupted soil moisture availability during entire crop growth period. Irrigation at early vegetative or branching stage perhaps had bought about the lively development of the crop while irrigation provided at flowering may have helped in maintaining size, duration and photosynthetic movement of the green plant parts subsequent to flowering and furthermore in movement of photosynthates to the sink [23]. Moreover, this is the period in which likely capsules and seed number is resolved.

Seed yield decreased with diminishing water availability [24] There was reduction in seed yield (976 kg $ha^{-1}$) when provided with 4 irrigations each at vegetative, flowering, capsule initiation and capsule filling stages ($T_7$). However, it was statistically at par (931 kg $ha^{-1}$) when 4 irrigations were scheduled each at vegetative, prebloom, flowering and capsule filling stages ($T_6$). Reduced seed yield in the later treatment in comparison to prior one might be due to stress imposed at capsule initiation stage which led to aversion in capsule formation and seed development.

Seed yield obtained with scheduling 3 irrigations each at vegetative, prebloom and capsule filling stages ($T_5$) was 616 kg $ha^{-1}$. With same number of irrigations each at vegetative, flowering and capsule filling stages ($T_4$), seed yield was noticed to be 818 kg $ha^{-1}$. The variance between the yield of both treatments could be attributed to termination of flowers and capsule formation due to stress imposed at flowering. Water deficiency during reproductive stage especially during flowering and capsule formation stage showed drastic reduction in seed yield [25,26]. Seed yield when provided with 2 irrigations each at vegetative and flowering stages was ($T_1$) 469 kg $ha^{-1}$ and was at par with irrigation scheduled at vegetative and capsule filling stages ($T_2$) (410 kg $ha^{-1}$) and treatment provided with 2 irrigations each at flowering and capsule filling stages ($T_3$) (485 kg $ha^{-1}$) of seed yield. In this way, not providing irrigation at flowering and capsule development period may have caused flower abortion which in turn showed diminished number of capsules and seeds in deficit irrigated treatments. This load of adverse impacts on yield attributes might have reduced the seed yield. Distinct variation among yields obtained under optimum and deficit irrigation shows that there is clear cut impact of water stress imposed at various stages of sesame crop.

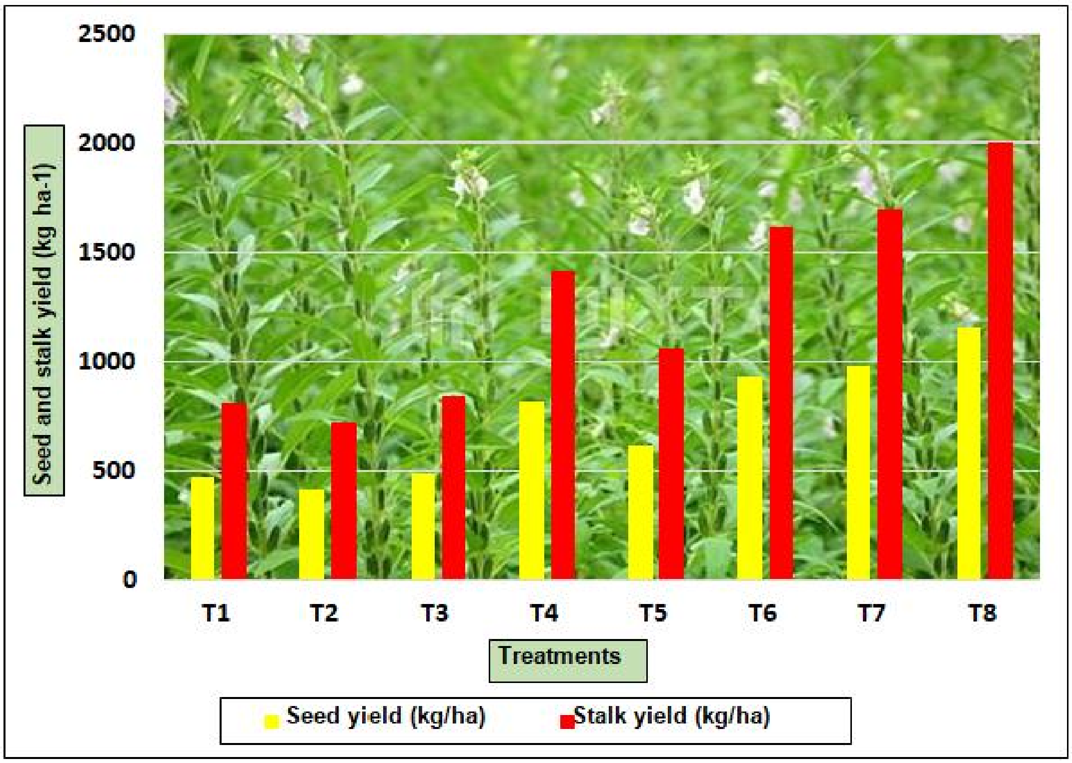
Among the deficit and optimum irrigated treatments, maximum stalk yield (1999 kg $ha^{-1}$) was noticed in treatment with 5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stages ($T_8$). Positive impact of optimum irrigation schedule on yield attributes fundamentally expanded seed and stalk yield of sesame over deficit irrigation schedule [27] Higher straw yield was ascribed to higher dry matter accumulation because of higher photosynthetic movement bringing about creation of higher photosynthates prompting better growth variables [28]. Followed to above optimum irrigation treatment, stalk yield noticed by scheduling 4 irrigations each at vegetative, flowering, capsule initiation and capsule filling stages ($T_7$) was 1695 kg $ha^{-1}$ and it was at par with treatment provided with same number of irrigations but at different growth stages ($T_6$) *i.e.,* vegetative, prebloom, flowering and capsule filling stages (1618 kg $ha^{-1}$). Stalk yield observed in treatment provided with 3 irrigations each at vegetative, flowering and capsule filling stages ($T_4$) was 1413 kg $ha^{-1}$ whereas treatment even though provided with same number of irrigations each at vegetative, prebloom and capsule filling stages ($T_5$) showed significantly lower stalk yield (1059 kg $ha^{-1}$) than prior one as it was lacking irrigation at flowering stage which led to reduced flower and capsule formation which in turn reduced the biological yield. This was supported by Mila *et al*. (2017). Lowest stalk yield (720 kg $ha^{-1}$) was registered in treatment provided with 2 irrigations each at vegetative and capsule filling stages ($T_2$). However, it was significantly on par with treatment with 2 irrigations applied each at vegetative and flowering stages (810 kg $ha^{-1}$).

### 3.3 Economics

The data regarding cost of cultivation, gross returns, net returns and benefit cost ratio of *summer* sesame as affected by deficit and optimum irrigation at various growth stages was presented in Table 2 and portrayed in Fig. 2. Cost of cultivation varied with change in number of irrigations applied with higher cost (34108 ₹ $ha^{-1}$) in treatment provided with 5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stages. Lowest (31108 ₹ $ha^{-1}$) was noticed in treatments provided with 3 irrigations *i.e.,* $T_1$, $T_2$ and $T_3$. The obtained results were in accordance with Sarkar *et al*. stating increase in cost of cultivation with increasing number of irrigations.

Higher gross and net returns (128499 and 94391 ₹ $ha^{-1}$, respectively) were obtained by scheduling 5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stages ($T_8$). These results can be attributed to higher yields due to continuous soil moisture availability throughout the growing season which in turn resulted in higher returns. Lowest gross and net returns (45820 and 14712 ₹ $ha^{-1}$) were noticed in treatment provided with 2 irrigations each at vegetative and capsule filling stages ($T_2$) Resultswere similar to findings of Puste et al. [12]

Benefit cost ratio in sesame as altered by deficit and optimum irrigation at different growth stages varied significantly in deficit and optimum irrigated treatments and keep to the similar trend as that of gross and net returns. Benefit cost ratio increased with increase in irrigation levels. Higher benefit cost proportion (2.76) was acquired in treatment provided with 5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stages ($T_8$). Lowest (0.47) was noticed with 2 irrigations scheduled each at vegetative and capsule filling stages ($T_2$). Hence allocation of deficit water at critical stages of sesame is important.




**$T_1$: 2 irrigations each at vegetative and flowering stages**
**$T_2$: 2 irrigations each at vegetative and capsule filling stages**
**$T_3$: 2 irrigations each at flowering and capsule filling stages**
**$T_4$: 3 irrigations each at vegetative, flowering and capsule filling stages**
**$T_5$: 3 irrigations each at vegetative, prebloom and capsule filling stages**
**$T_6$: 4 irrigations each at vegetative, prebloom, flowering and capsule filling stages**
**$T_7$: 4 irrigations each at vegetative, flowering, capsule initiation and capsule filling stages**
**$T_8$: 5 irrigations each at vegetative, prebloom, flowering, capsule initiation andcapsule filling stages**

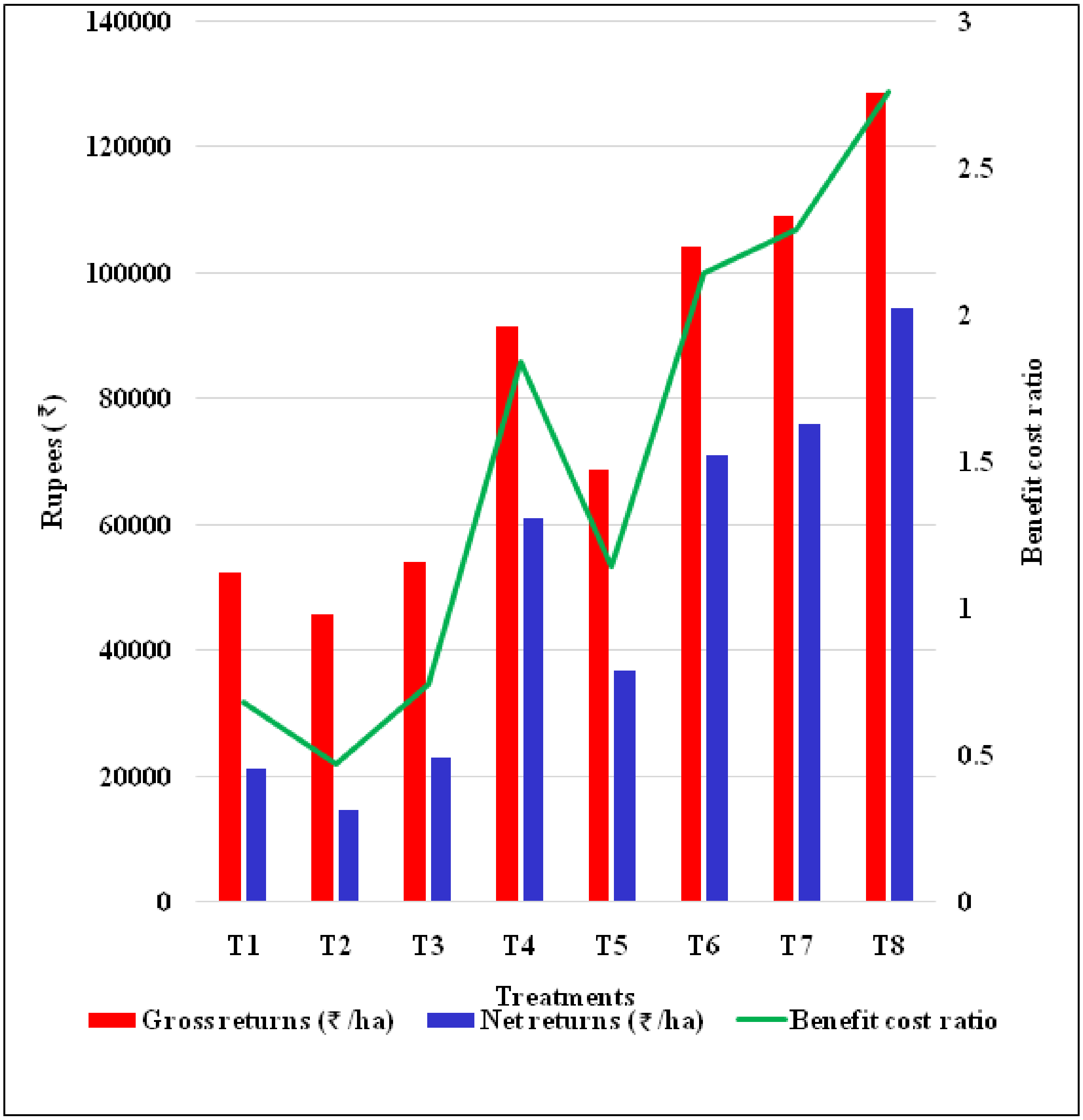
**Fig. 1. Seed yield and stalk yield (kg $ha^{-1}$) in sesame as effected by deficit and optimum irrigation at various growth stages**

**Table 1. Yield attributes and yield of *summer* sesame as influenced by deficit and optimum irrigation at various growth stages**

| | Treatments | No of capsules plant$^{-1}$ | Capsule weight (g) | No of filled seeds capsule$^{-1}$ | Seed yield (kg ha$^{-1}$) | Stalk yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|
| $T_1$ | 2 irrigations each at vegetative and flowering stage | 13.0 | 0.23 | 30.8 | 469 | 810 |
| $T_2$ | 2 irrigations each at vegetative and capsule filling stage | 10.4 | 0.21 | 29.5 | 410 | 720 |
| $T_3$ | 2 irrigations each at flowering and capsule filling stage | 12.3 | 0.22 | 31.4 | 485 | 840 |
| $T_4$ | 3 irrigations each at vegetative, flowering and capsule filling stage | 25.7 | 0.27 | 43.9 | 818 | 1413 |
| $T_5$ | 3 irrigations each at vegetative, prebloom and capsule filling stage | 18.7 | 0.24 | 38.1 | 616 | 1059 |
| $T_6$ | 4 irrigations each at vegetative, prebloom, flowering and capsule filling stage | 33.6 | 0.28 | 47.5 | 931 | 1618 |
| $T_7$ | 4 irrigations each at vegetative, flowering, capsule initiation and capsule filling stage | 35.1 | 0.28 | 48.9 | 976 | 1695 |
| $T_8$ | 5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stage | 45.0 | 0.32 | 55.0 | 1150 | 1999 |
| SEm± | | 1.67 | 0.01 | 1.82 | 33.36 | 39.16 |
| CD @5% | | 5.06 | 0.03 | 5.53 | 101.20 | 118.78 |
| CV (%) | | 11.93 | 6.4 | 7.8 | 7.9 | 5.3 |

**Table 2. Cost of cultivation, Gross returns, Net returns and Benefit cost ratio of summer sesame as effected by deficit and optimum irrigation at various crop stages**

| | Treatments | Cost of cultivation (₹ ha$^{-1}$) | Gross returns (₹ ha$^{-1}$) | Net returns (₹ ha$^{-1}$) | Benefit cost ratio |
|---|---|---|---|---|---|
| $T_1$ | 2 irrigations each at vegetative and flowering stage | 31108 | 52400 | 21292 | 0.68 |
| $T_2$ | 2 irrigations each at vegetative and capsule filling stage | 31108 | 45820 | 14712 | 0.47 |
| $T_3$ | 2 irrigations each at flowering and capsule filling stage | 31108 | 54188 | 23080 | 0.74 |
| $T_4$ | 3 irrigations each at vegetative, flowering and capsule filling stage | 32108 | 91393 | 60951 | 1.84 |
| $T_5$ | 3 irrigations each at vegetative, prebloom and capsule filling stage | 32108 | 68819 | 36711 | 1.14 |
| $T_6$ | 4 irrigations each at vegetative, prebloom, flowering and capsule filling stage | 33108 | 104028 | 70920 | 2.14 |
| $T_7$ | 4 irrigations each at vegetative, flowering, capsule initiation and capsule filling stage | 33108 | 109055 | 75947 | 2.29 |
| $T_8$ | 5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stage | 34108 | 128499 | 94391 | 2.76 |
| SEm± | | - | 3002.23 | 2912.75 | 0.12 |
| CD @5% | | - | 9106.33 | 8834.92 | 0.37 |
| CV (%) | | - | 6.4 | 10.1 | 14.0 |




**$T_1$:2 irrigations each at vegetative and flowering stages**
**$T_2$:2 irrigations each at vegetative and capsule filling stages**
**$T_3$:2 irrigations each at flowering and capsule filling stages**
**$T_4$: 3 irrigations each at vegetative, flowering and capsule filling stages**
**$T_5$:3 irrigations each at vegetative, prebloom and capsule filling stages**
**$T_6$:4 irrigations each at vegetative, prebloom, flowering and capsule filling stages**
**$T_7$:4 irrigations each at vegetative, flowering, capsule initiation and capsule filling stages**
**$T_8$:5 irrigations each at vegetative, prebloom, flowering, capsule initiation and capsule filling stages**

**Fig. 2. Gross returns (₹ $ha^{-1}$), net returns (₹ $ha^{-1}$) and benefit cost ratio in sesame as influenced by deficit and optimum irrigation at various growth stages**

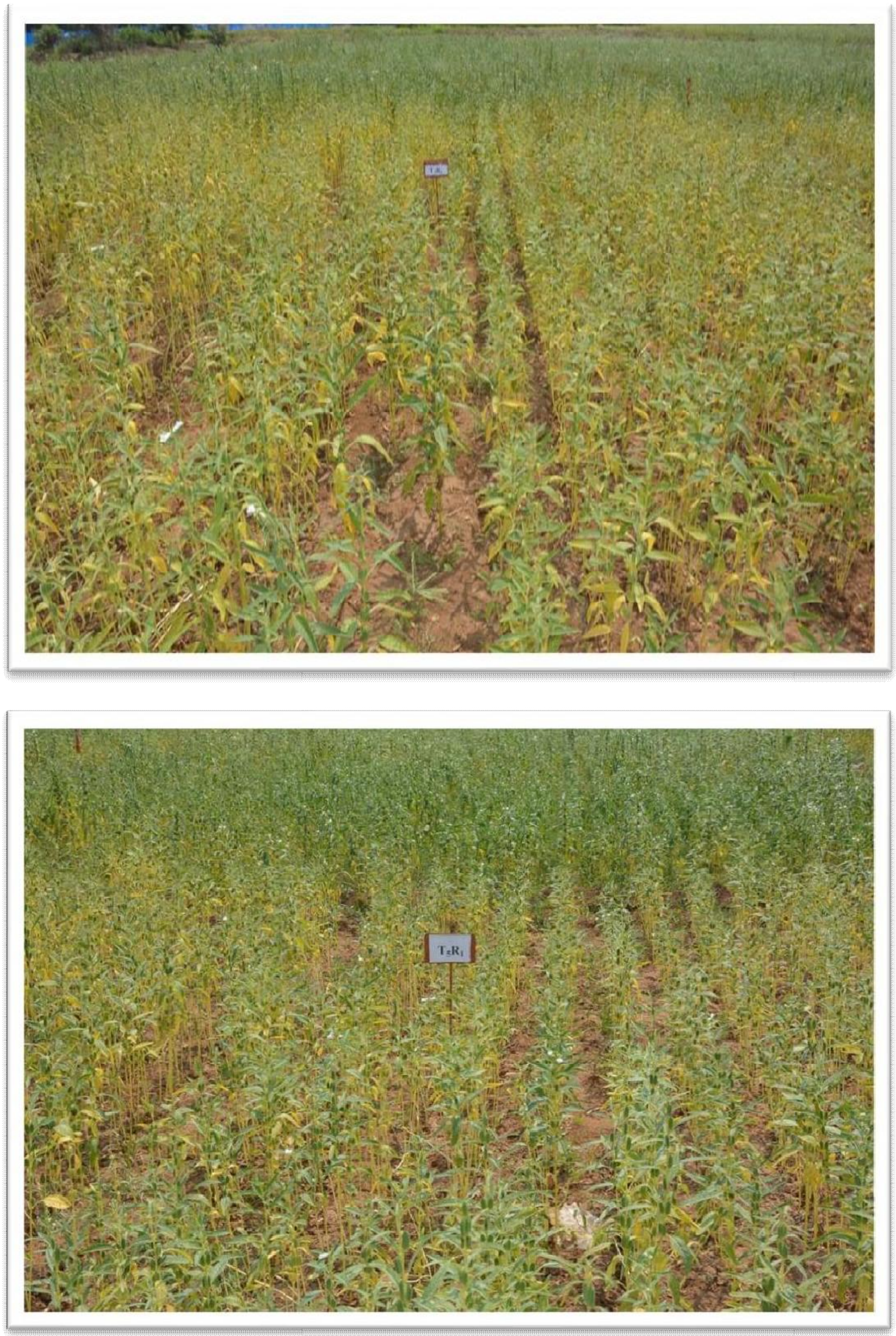



**Fig. 3. Performance of treatments subjected to moisture stress at flowering ($T_2$ and $T_5$)**

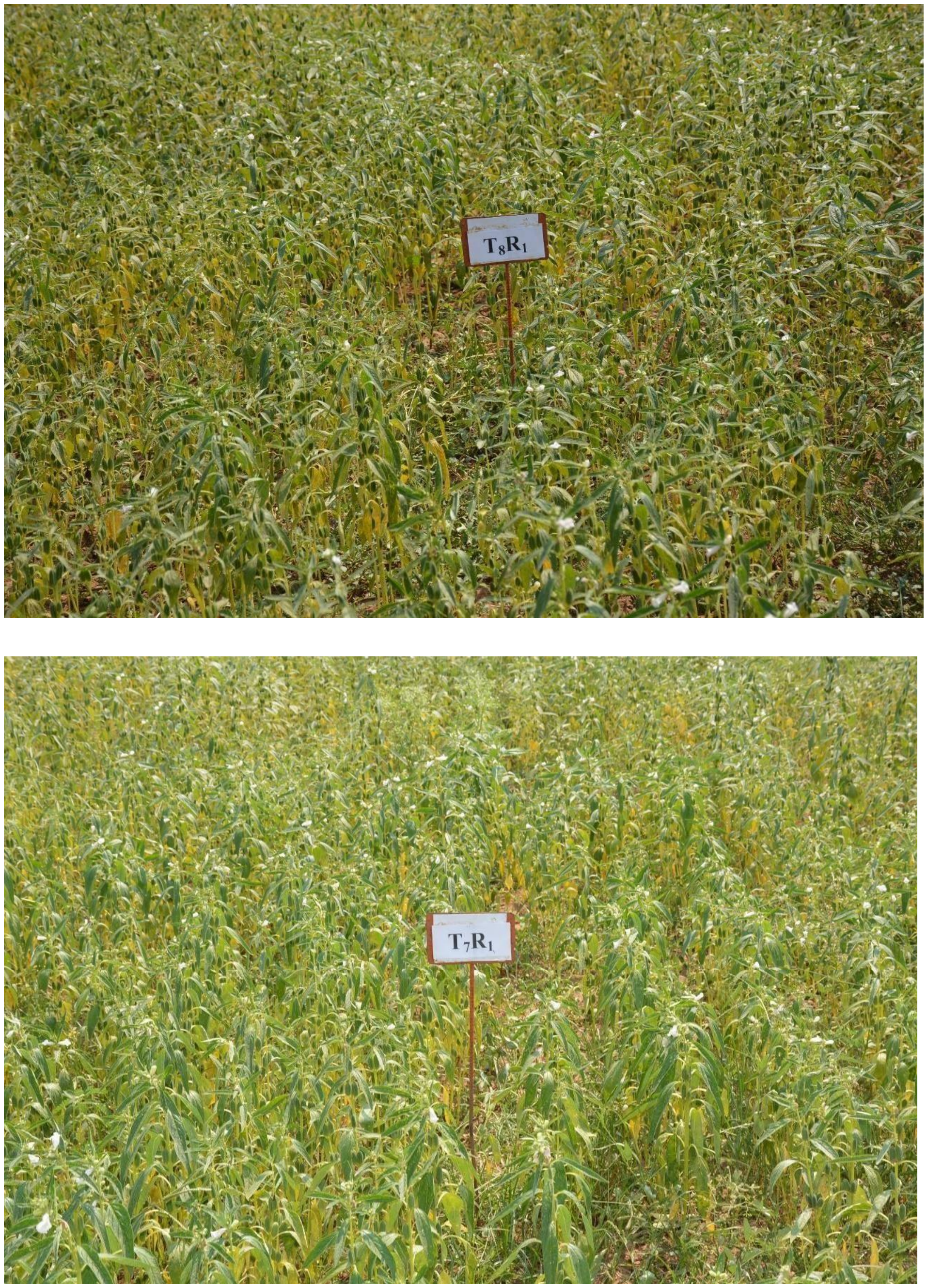



**Fig. 4. Comparison of $T_7$ and $T_8$ at capsule filling stage**

## 4. CONCLUSION

From the outcomes obtained in the current study, it is concluded that scheduling 5 irrigations at various growth stages *i.e.,* vegetative, prebloom, flowering, capsule initiation and capsule filling stages proved to be superior with higher yield attributing characters, yield and benefit cost ratio of *summer* sesame.

## 5. FUTURE SCOPE

1. Study on deficit and optimum irrigation and critical analyses of water use parameters in organically cultivated sesame.
2. Scheduling of irrigation in *summer* sesame grown with preceding crops *i.e.,* rice, turmeric, redgram, cotton etc.
3. Study on varied levels of irrigation at different

growth stages of sesame in cropping system approach need to be studied.
4. Performance of existing popular varieties of sesame under different irrigation regimes at various growth stages for their suitability in different agroclimatic zones.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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