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Interactive Effect of Nitrogen, Zinc (Zn) and Iron (Fe) on the Growth and yield Characteristics of Gobhi Sarson (*Brassica napus* 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.

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ABSTRACT

Brassica napus L., commonly known as Gobhi Sarson in India, is a vital oilseed crop contributing significantly to the agricultural economy. India stands as the fourth-largest producer of oilseeds, with mustard-rapeseed, including *Brassica napus*, constituting about 28.6% of the total oilseed production [1]. The experiment titled "Study on Foliar Application of Nitrogen, Zinc (Zn), and Iron (Fe) on the Growth and Yield Characteristics of Gobhi Sarson (*Brassica napus* L.)" was conducted at the research farm of Lovely Professional University, Punjab, during the Rabi season of 2023-24.

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A total of nine treatments with three replications were evaluated using a Randomized Block Design. The findings indicate that Treatment 9 (75%RDF + 1% Urea + 0.5% FeSO4 + 0.5% ZnSO4) demonstrated the highest plant height, fresh weight, dry weight, leaf area, primary and secondary branches per plant, number of siliquae per plant, seeds per siliquae, 1000-seed weight, seed yield, biological yield, and oil content. Treatment 5 (50%RDF + 1% Urea + 0.5% FeSO4 + 0.5% ZnSO4) also performed well across these parameters, albeit to a slightly lesser extent. (T9) recorded the highest seed yield (19.7 q ha-1), significantly outperforming all other treatments, with Treatment 5 being statistically comparable. Moreover, Treatment 9 exhibited the maximum oil content (41.2%), followed closely by Treatment 5 with oil content of 40.6%. Conversely, the control treatment (T1) yielded the lowest oil content. These results underscore the efficacy of foliar application of 75% RDF with 1% Urea, 0.5% FeSO4, and 0.5% ZnSO4 in enhancing the growth and yield characteristics of Gobhi Sarson, with Treatment 5 showing similar trends.

Keywords: Gobhi sarson; nitrogen; Iron; zinc; growth parameters; yield attributes.

1. INTRODUCTION

1.1 Overview of *Brassica napus* L. Cultivation and Its Importance

Brassica napus L., commonly known as Gobhi Sarson in India, is a vital oilseed crop contributing significantly to the agricultural economy. India stands as the fourth-largest producer of oilseeds, with mustard-rapeseed, including *Brassica napus*, constituting about 28.6% of the total oilseed production [1]. This crop is predominantly grown in regions like Punjab, Haryana, and Himachal Pradesh due to its adaptability to the climatic conditions and its high oil content, which averages around 44.5%. The oil extracted from *Brassica napus* seeds is rich in monounsaturated and polyunsaturated fatty acids, including omega-3 and omega-6, offering substantial health benefits [1].

Additionally, it has a larger percentage of high-quality oil (41–45%) with a high concentration of important fatty acids, such as oleic, linoleic, and linolenic acid. Indian mustard is being replaced by this new oilseed crop, which is only grown in a small region in Punjab, Haryana, and Himachal Pradesh. Gobhi sarson is a long-duration crop that typically grows as a solitary crop, taking 150–170 days to mature. Due to photosensitivity and thermos sensitivity, this crop grows extremely slowly up until mid-January, when it is in the vegetative phase. However, when the environment becomes more favourable later in the reproductive phase, the crop grows quickly and robustly. Because of this, it needs larger row spacing than the other crops in this category. During the early phases of this crop's growth, there is a lot of room for intercropping compatible and non-competitive crops to increase total production. *Brassica napus* L. has been successfully interplanted with a variety of crops, including toria [2,3], oats Singh 2013 and Jamwal [4] in various agroclimatic zones of the nation.

1.2 Significance of Micronutrients (N, Zn, Fe) in Crop Production

Micronutrients such as Nitrogen (N), Zinc (Zn), and Iron (Fe) play critical roles in the physiological and biochemical processes of plants, affecting their growth, yield, and quality. Nitrogen is a key component of chlorophyll and amino acids, essential for photosynthesis and protein synthesis. Zinc acts as a cofactor for several enzymes, influencing DNA synthesis, protein formation, and growth regulation. Iron is crucial for chlorophyll synthesis and acts as a catalyst in various biochemical pathways [5]. The deficiency of these micronutrients can lead to reduced crop productivity and poor seed quality, underscoring the need for appropriate nutrient management practices.

1.3 Justification for the Study and Potential Benefits of Foliar Application

Foliar application of fertilizers, as opposed to traditional soil application, presents a method with numerous benefits for crop cultivation. This technique involves the direct application of nutrients to plant leaves, allowing for a more efficient and targeted delivery of essential elements like nitrogen (N), zinc (Zn), and iron (Fe). These nutrients play pivotal roles in plant physiology, influencing processes such as chlorophyll synthesis, enzyme activation, and overall plant metabolism. The foliar feeding method is particularly advantageous for its higher nutrient use efficiency. Plants can absorb and utilize nutrients more rapidly through their leaves than through root uptake from the soil. This efficiency is crucial for the swift correction of nutrient deficiencies, which can be vital during critical growth stages of crops like *Brassica napus*, commonly known as canola or rapeseed. Moreover, foliar application minimizes environmental impact. By reducing the amount of fertilizer that leaches into the soil, it lessens the risk of groundwater contamination and eutrophication of water bodies. This method also aligns with sustainable agriculture practices by promoting the judicious use of inputs. Research into the efficacy of foliar application on *Brassica napus* could yield significant insights. Optimizing the timing and concentration of foliar sprays could enhance the yield and quality of the crop, leading to better management practices that support both agricultural productivity and environmental stewardship.

2. MATERIALS AND METHODS

The experiment was carried out during Rabi in the Lovely Professional University's School of Agriculture's research fields in Phagwara, Punjab in 2023–2024. The Hayola ADV 405 type of mustard-rapeseed was used. Fertilizer dosage recommendations are 40:12:0 kg/ha (N:P:K). Punjab is located in the Trans-Gangetic Plains Zone, which is the sixth Argo-climatic zone. The district is located between the Sutlej and Beas rivers in the center of Punjab. In terms of location, the plot is positioned at 31^0 14' 34.62" North latitude, 75^0 41' 48.91" East longitude, an average elevation of 252 meters above mean sea level. Punjab receives rainfall from both the southwest and northeast monsoons. The rainfall is mostly in the monsoon period from June to August. Typically, the winter season begins around the end of October and lasts through the end of February. The first two weeks of November see a decrease in temperature, which reaches its lowest point in either December or January, making those months the coldest of the year. Summer officially begins in the middle of February and lasts until the first two weeks of June. May is the warmest month of the year since it is the month when the temperature starts to rise in February and reaches its highest point. revealed the experimental plot's soil had a sandy loam texture, was medium in available nitrogen (175.2 kg/ha), low in available phosphorus (25.2 kg/ha), and moderately low in organic carbon (0.34%). It also had low levels of accessible potassium (217.8 kg/ha). The experiment was conducted in Randomized Block Design with 3 Replications and 9 Treatments *viz*., 100% RDF (Control) (T1), 50%RDF + 1% Urea (T2), 50% RDF + 0.5% FeSO4 (T3), 50% RDF + 0.5% ZnSO4 (T4), 50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 (T5), 75%RDF +1% Urea (T6), 75% RDF + 0.5% ZnSO4 (T7), 75%RDF + 0.5% FeSO4 (T8), 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 (T9).

The observations were recorded as 5 plants were randomly selected in each net plot. Plant growth parameters like plant height, leaf area, Fresh weight, dry weight, primary branches, secondary branches and yield parameters like number of siliquae per plant, number of seeds per siliquae, Test weight, seed yield and biological yield, Oil content.

3. RESULTS AND DISCUSSION

3.1 Plant Height

Plant height serves as a pivotal indicator of growth dynamics and the crop's competitive prowess against weed interference. Throughout the crop's growth stages, namely at 30, 60, and 90 days after sowing (DAS), as well as at harvest, variations in plant height were observed across different treatments presented in (Table 1., Fig. 1.). The data is presented in Table 1. At 30 DAS, the control (T1) exhibited the lowest plant height, measuring at 10.6 cm, while (T9), comprising 75% RDF, 1% Urea, 0.5% FeSO4, and 0.5% ZnSO4, recorded the highest height at (17.9 cm). This trend persisted at 60 DAS, with T9 showing the tallest plants (30.4 cm) compared to the shortest in T1 (23.6 cm). By 90 DAS, T9 displayed remarkable plant height, reaching (134.5 cm), significantly outstripping T1's height of 76.2 cm. At harvest, T9 continued to demonstrate superiority in plant height, towering at 183.5 cm, while T1 remained comparatively shorter at 156.3 cm. Consistently, treatments incorporating (T9)75% RDF, 1% Urea, 0.5% FeSO4, and 0.5% ZnSO4 showcased enhanced plant height across all growth stages. This suggests the synergistic effect of these components in bolstering growth dynamics, potentially attributed to improved nutrient uptake and utilization efficiency. The taller stature conferred by these treatments implies a greater ability to compete with weeds for light and other resources, thereby enhancing crop productivity. These findings underscore the significance of optimizing fertilizer formulations to maximize growth parameters, ultimately contributing to improved crop yield and quality. And the similar results were reported by Kamaldeep kaur *et al.,* [6].

Table 1. Plant height

Treatments	30 DAS	60 DAS	90 DAS	At harvest
100% RDF (Control)	10.6	23.6	76.2	156.3
50%RDF + 1% Urea	11.3	24.3	112.2	164.9
50% RDF + 0.5% FeSO4	14.4	24.6	121.5	161.4
50% RDF + 0.5% ZnSO4	12.5	24.6	122.8	166.0
50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	14.3	29.0	128.6	178.0
75%RDF +1% Urea	12.1	24.3	116.7	166.7
75% RDF + 0.5% ZnSO4	12.1	27.4	125.0	163.7
75%RDF + 0.5% FeSO4	12.1	25.3	127.1	169.3
75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	17.9	30.4	134.5	183.5
S. Em (±)	1.10	0.32	1.86	0.52
C.D. @ 5%	3.27	0.95	5.53	1.55

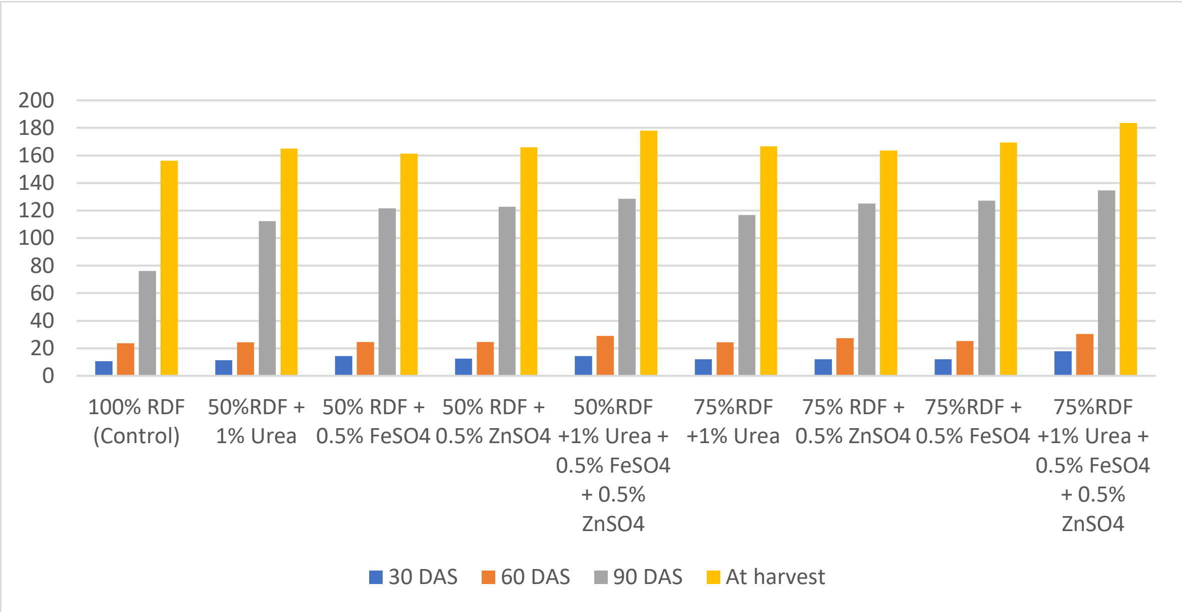

Fig. 1. Plant height as influenced by various treatments

3.2 Leaf area (cm^2)

The data related to Leaf area is presented in Table 2 and Fig. 2. At 30DAS, treatment with (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest leaf area (15.3 cm^2) and treatments with RDF Control (T1) recorded significantly lowest Leaf area (11.8 cm^2). At 60 DAS, treatment with (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest Leaf area (41.1 cm^2) and treatment with RDF Control (T1) recorded considerably lowest Leaf area (25.3 cm^2) and treatments 50%RDF + 1% Urea, 50% RDF + 0.5% FeSO4, 50% RDF + 0.5% ZnSO4 were statistically at par with the treatment 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4. At 90 DAS, treatment with (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest Leaf area (140.7 cm^2) and treatment with RDF Control (T1) recorded considerably lowest Leaf area (128.4 cm^2). The enhanced leaf area observed under treatment (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 can be attributed to the better nutritional status provided by the combination of nutrients. Larger leaf areas enhance the plant's ability to capture sunlight and improve gas exchange, leading to more robust growth and development. This aligns with studies such as those Kumari Thakur, Ratnesh [7], Bhagat *et al.*, [8] which link nutrient availability to leaf morphology changes.

Table 2. Leaf area (cm^2)

Treatments	30 DAS	60 DAS	90 DAS
100% RDF (Control)	11.8	25.3	128.4
50%RDF + 1% Urea	13.3	32.8	131.0
50% RDF + 0.5% FeSO4	13.6	31.9	131.5
50% RDF + 0.5% ZnSO4	13.4	30.0	130.6
50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	14.6	39.3	134.5
75%RDF +1% Urea	13.3	33.8	132.0
75% RDF + 0.5% ZnSO4	13.7	33.7	132.2
75%RDF + 0.5% FeSO4	13.5	33.4	131.2
75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	15.3	41.1	140.7
S. Em (±)	0.29	1.91	0.74
C.D. @ 5%	0.87	5.68	2.20

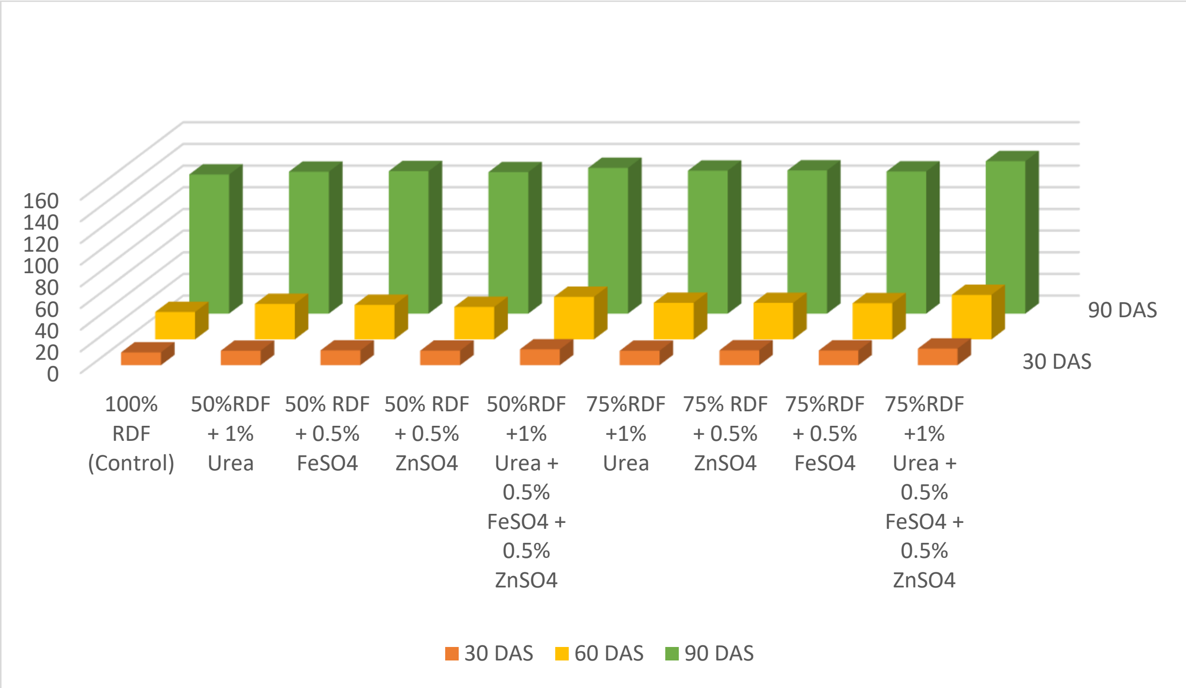

Fig. 2. Area of Leaf influenced by various treatments

3.3 Fresh Weight

Fresh weight was recorded at 30, 60 and 90 DAS. The results are presented in the Table 3. And Fig. 3. At 30DAS, treatment with (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest fresh weight (27.3 gm) and treatments with RDF Control (T1) recorded significantly lowest fresh weight (11.7 gm). At 60 DAS, treatment with (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest fresh weight (106.8 gm) and treatment with RDF Control (T1) recorded considerably lowest fresh weight (76.5 gm) and treatments 50%RDF + 1% Urea, 50% RDF + 0.5% FeSO4, 50% RDF + 0.5% ZnSO4 were statistically at par with the treatment 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4. At 90 DAS, treatment with (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest fresh weight (430 gm) and treatment with RDF Control (T1) recorded considerably lowest fresh weight (398.7 gm). The superior performance of treatment (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 in terms of fresh weight can be primarily attributed to the optimal nutrient balance provided by the combination of nitrogen, iron, and zinc. Iron and zinc are essential micronutrients that enhance several physiological functions, including chlorophyll synthesis and enzyme activity crucial for plant metabolism. The synergistic effect of combining these nutrients enhances overall plant biomass more effectively than when applied individually or in less balanced proportions.

Table 3. Fresh weight

Treatments	30 DAS	60 DAS	90 DAS
100% RDF (Control)	11.7	76.5	398.7
50%RDF + 1% Urea	20.0	86.3	406.0
50% RDF + 0.5% FeSO4	19.8	82.1	408.3
50% RDF + 0.5% ZnSO4	20.0	82.4	415.3
50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	26.2	101.8	424.7
75%RDF +1% Urea	21.7	94.5	408.0
75% RDF + 0.5% ZnSO4	21.8	77.0	414.0
75%RDF + 0.5% FeSO4	22.7	82.1	419.7
75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	27.3	106.8	430.0
S. Em (±)	0.73	2.06	1.38
C.D. @ 5%	2.19	6.13	4.10

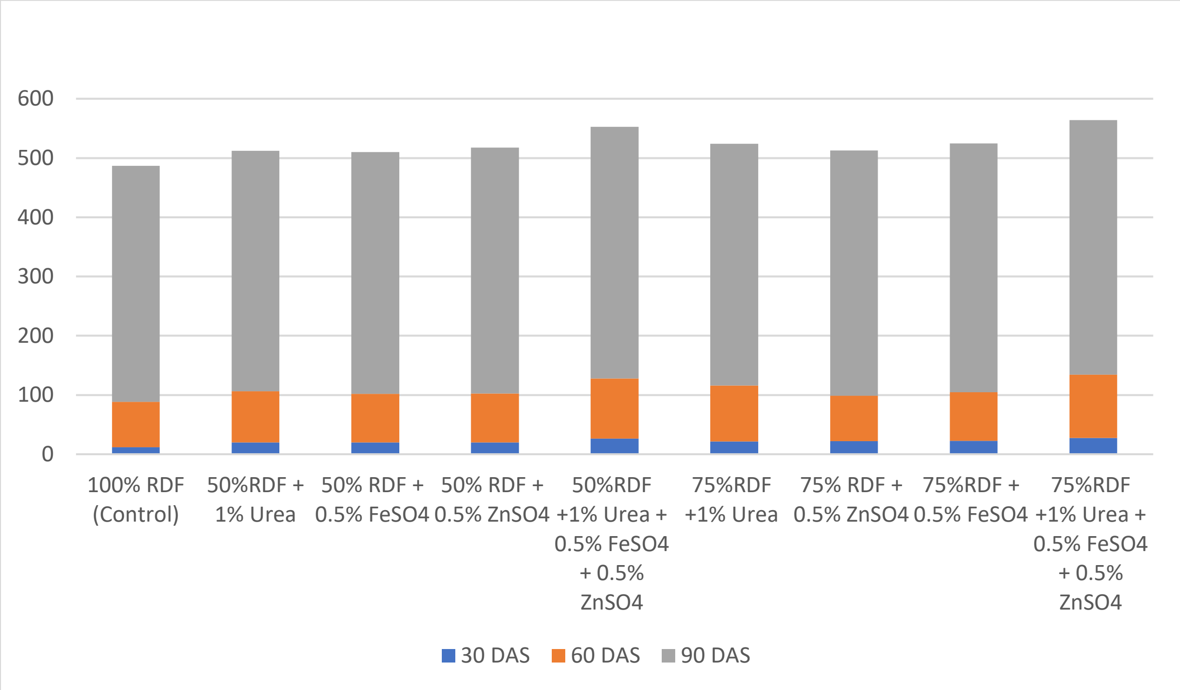

Fig. 3. Fresh weight as influenced by various treatments

3.4 Dry Weight

Dry weight was observed at different times in growing season. The results are listed in the Table 4. And Fig. 4. At 30DAS, treatment with (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest Dry weight (3 gm) and treatments with RDF Control (T1) recorded significantly lowest Dry weight (1.4 gm). At 60 DAS, treatment with (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest Dry weight (15.6 gm) and treatment with RDF Control (T1) recorded considerably lowest Dry weight (12.3 gm) and treatments 50%RDF + 1% Urea, 50% RDF + 0.5% FeSO4, 50% RDF + 0.5% ZnSO4 were statistically at par with the treatment 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4. At 90 DAS, treatment with (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest Dry weight (45.5 gm) and treatment with RDF Control (T1) recorded considerably lowest Dry weight (43.4 gm). The increased dry weight in treatment (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 suggests an enhanced metabolic efficiency and growth, likely due to the optimal nutrient availability. The presence of both macronutrients and essential micronutrients such as nitrogen, iron, and zinc can enhance photosynthetic capacity and energy conversion efficiency, as noted by the similar results are also seen in findings of Bhagat *et al*., [8], Rameti Jangir *et al*., [9].

Table 4. Dry weight

Treatments	30 DAS	60 DAS	90 DAS
100% RDF (Control)	1.4	12.3	43.4
50%RDF + 1% Urea	1.8	13.4	43.8
50% RDF + 0.5% FeSO4	2.1	13.4	44.4
50% RDF + 0.5% ZnSO4	1.9	12.7	44.6
50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	2.8	14.7	44.9
75%RDF +1% Urea	2.3	13.9	44.0
75% RDF + 0.5% ZnSO4	2.4	12.6	44.3
75%RDF + 0.5% FeSO4	1.9	12.9	44.6
75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	3.0	15.6	45.5
S. Em (±)	0.26	0.37	0.18
C.D. @ 5%	0.78	1.12	0.55

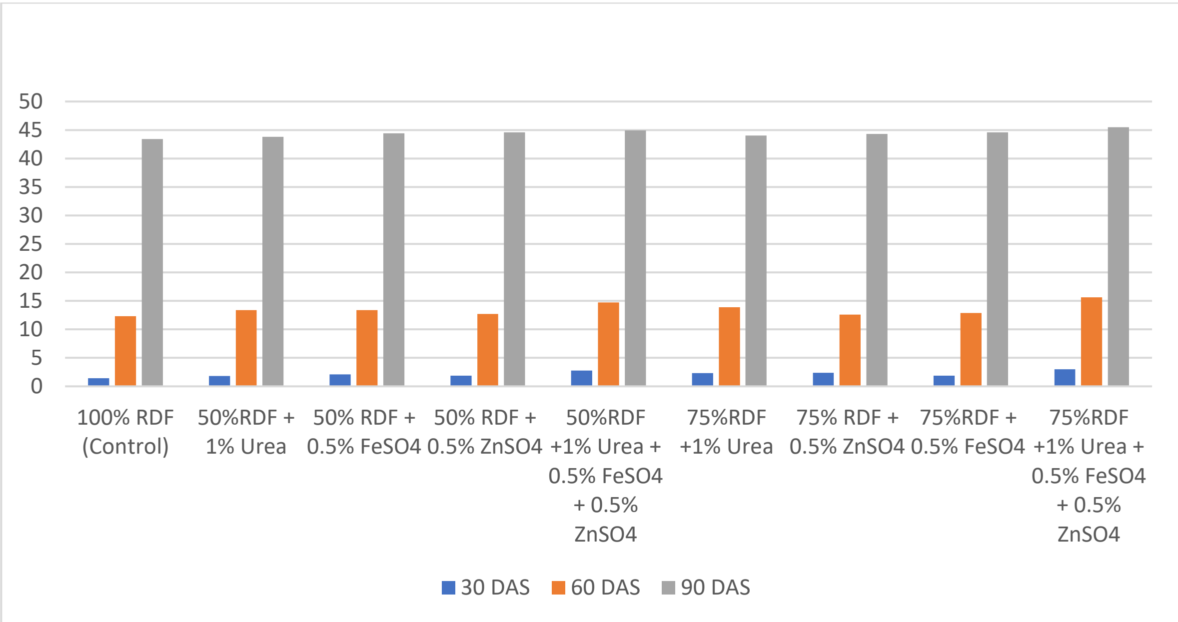

Fig. 4. Dry weight as influenced by various treatments

3.5 Number of Primary Branches

The main branches give the plant the canopy architecture. Application of combinations of nitrogen, iron and zinc significantly affected the number of primary branches per plant (Table 5 and Fig. 5). Primary branches per plant were maximum (6.57) using 75% RDF + 1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 (T9) and significantly higher than all other treatments. Kumar (2000) also reported significant growth in primary and secondary branches of gobhi sarson. Different combinations of nitrogen, Zinc and Iron treatments significantly affected the number of primary branches per plant. The maximum number of primary branches per facility was recorded (6.57). This 75% RDF + 1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 which was statistically equal to 50% RDF + 1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 but statistically higher than the other processing. The lowest number of primary branches per facility (4.68) was recorded in the RDF control. The increased number of primary branches in treatment T9 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 suggests a stimulatory effect of the nutrient combination on branching patterns. This could be attributed to the balanced supply of macronutrients and micronutrients, which are essential for promoting lateral shoot growth and branching. Previous studies, such as Kaur *et al*., [10], Gangadhar *et al.,* [11] have demonstrated the role of nitrogen, iron, and zinc in regulating branch development through their influence on hormone signaling pathways.

Table 5. Primary branches and Secondary branches

Treatments	Primary branches	Secondary branches
100% RDF (Control)	4.68	5.13
50%RDF + 1% Urea	5.59	6.37
50% RDF + 0.5% FeSO4	5.38	7.10
50% RDF + 0.5% ZnSO4	5.56	6.43
50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	5.95	7.28
75%RDF +1% Urea	5.71	6.49
75% RDF + 0.5% ZnSO4	5.50	7.21
75%RDF + 0.5% FeSO4	5.61	6.53
75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	6.57	8.41
S. Em (±)	0.03	0.07
C.D. @ 5%	0.10	0.22

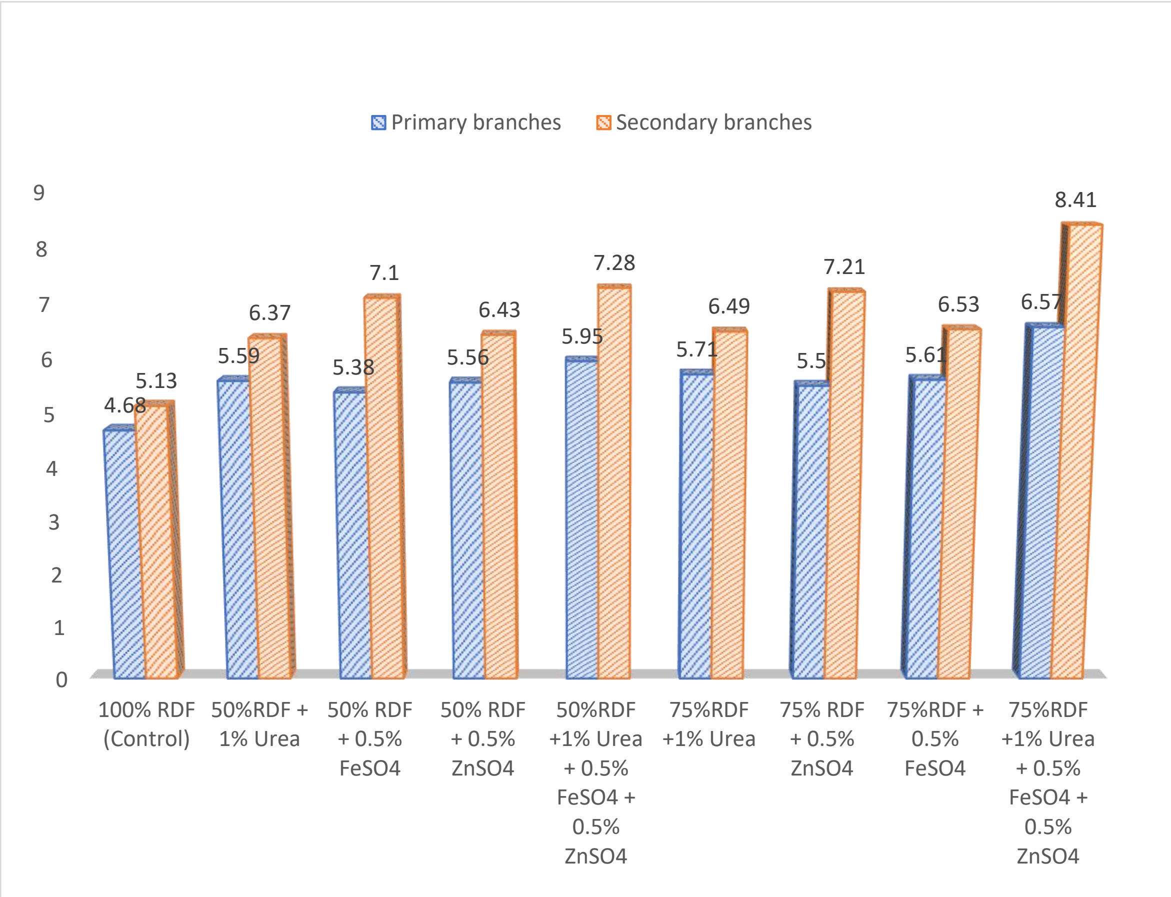

Fig. 5. Primary and secondary branches as influenced by various treatments

3.6 Number of Secondary Branches

Number of secondary branches per plant of gobhi sarson was significantly influenced by application of different combinations of Nitrogen, Iron, Zinc (Table 5 and Fig. 5.). The secondary branches per plant were maximum (8.41) with the application of 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 (T9) and significantly higher than all other treatments. Maximum number of secondary branches per plant (8.41) were recorded. That 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, which was statistically par with 50%RDF +1% Urea + 0.5% FeSO4 +

0.5% ZnSO4, but statistically higher than other treatments. The lowest number of secondary branches per plant (5.13) was recorded in RDF control. The significant increase in secondary branches in treatment T9 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 suggests that the balanced nutrient supply positively influenced lateral branching. Nitrogen, in the form of urea, is known to promote vegetative growth and lateral shoot development. Additionally, the presence of iron and zinc may have facilitated the formation of secondary branches through their roles in hormone regulation and enzyme activation. These findings align with research by Deekshith *et al.,* [12], V Guptha *et al.,* [13] highlighting the importance of micronutrients in modulating branching patterns.

3.7 Number of Siliquae Per Plant

Treatment 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 (T9) with recorded significantly Highest number of siliquae per plant (372) and treatments with RDF control shows lowest number of siliquae per plant (271) presented in Table 6., Fig. 6., that 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, which was statistically par with 50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, but statistically higher than other treatments. The increased number of siliquae per plant in treatment (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 suggests that the balanced nutrient supply positively influenced reproductive development. Nitrogen, provided by urea, is known to promote flowering and fruit set, leading to increased siliqua formation. Additionally, the presence of iron and zinc may have enhanced reproductive processes through their roles in enzyme activation and hormone regulation. Previous studies, such as Singh, Thakar *et al.,* [14], Dalip *et al.,* [15] have demonstrated the importance of micronutrients in improving reproductive yield in various crop species.

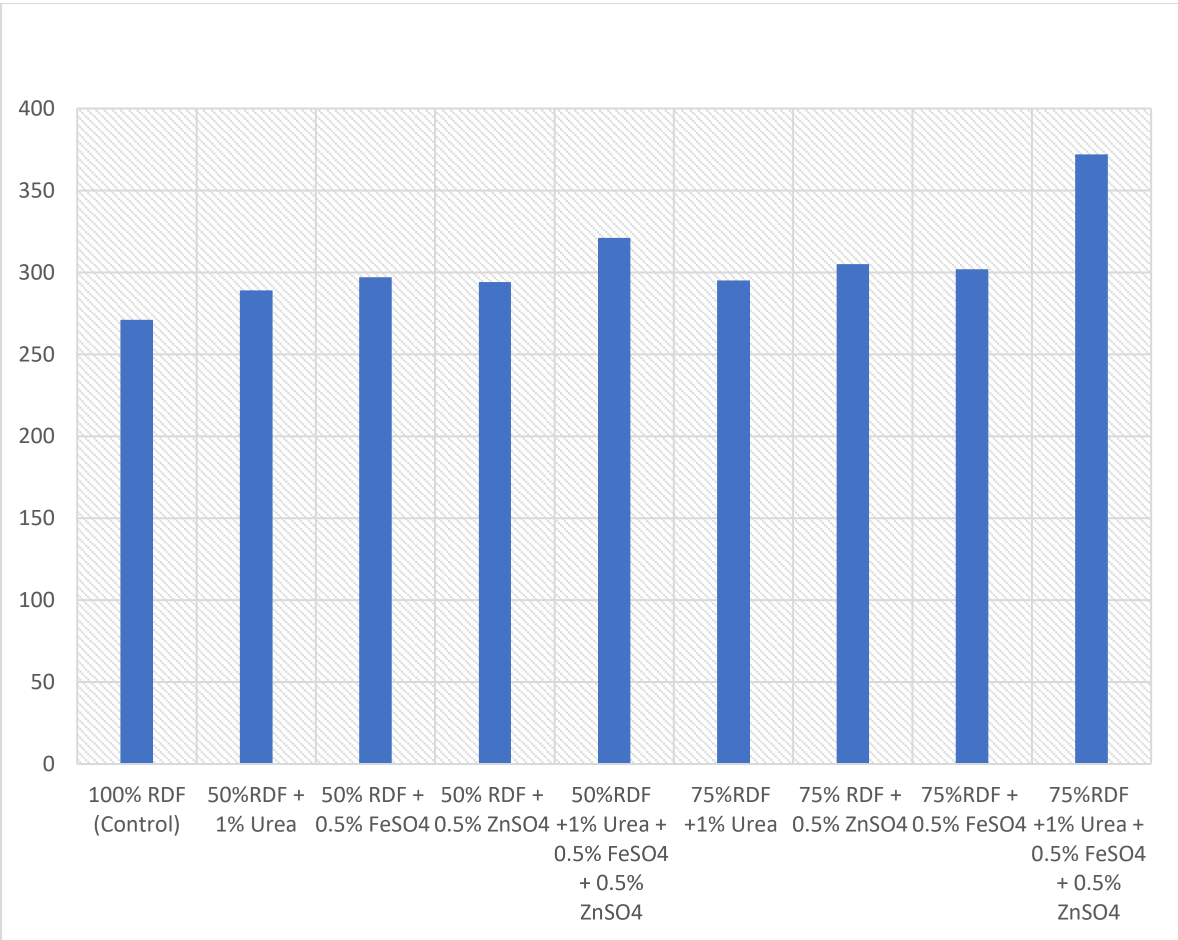

Fig. 6. Number of siliquae/ plant

Table 6. Number of siliquae/plant

Treatments	Number of Siliquae/ Plant
100% RDF (Control)	271
50%RDF + 1% Urea	289
50% RDF + 0.5% FeSO4	297
50% RDF + 0.5% ZnSO4	294
50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	321
75%RDF +1% Urea	295
75% RDF + 0.5% ZnSO4	305
75%RDF + 0.5% FeSO4	302
75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	372
S. Em (±)	4.18
C.D. @ 5%	12.4

3.8 Number of Seeds Per Siliquae

The number of seeds per Siliquae is also a significant yield-increasing character. Data on number of seeds per silique as affected by different treatment combinations as shown in Table 7. The maximum number of seeds per siliquae (19.1) was recorded in (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 and lowest number of siliquae is recoded in RDF control (17.2). that 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, which was statistically par with 50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, but statistically higher than other treatments. The increased number of seeds per siliquae in treatment (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 suggests that the balanced nutrient supply positively influenced seed development and filling. Nitrogen, provided by urea, is known to enhance seed set and seed filling processes. Findings such as Sarlach [16] reported same results. Additionally, the presence of micronutrients such as iron and zinc may have played a role in improving seed quality and filling by regulating enzymatic activities involved in seed development.

3.9 Test Weight (gm)

Development can be judged through thousand seed weight parameter. The data revealed that 1000 seed weight of gobhi sarson was increased in 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 (Table 7 and Fig. 7). Maximum seed weight (5.07 g) was observed in (T9) 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 and lowest seed weight (4.62) was recorded in RDF control. that 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, which was statistically par with 50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, but statistically higher than other treatments. The increased seed weight in treatment T9 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 suggests that the balanced nutrient supply positively influenced seed development and filling. Nitrogen, provided by urea, is known to enhance seed set and seed filling processes, resulting in heavier seeds. Additionally, the presence of micronutrients such as iron and zinc may have played a role in improving seed quality and filling by regulating enzymatic activities involved in seed development and storage compound accumulation. Previous studies, such as Bhaghat *et al.,* [17], Randeep et al., [18] had reported similar results.

3.10 Seed Yield (q/ha)

The final product, or seed yield, is the net effect of several agronomic inputs that affect the growth and yield-attributing characteristics of the crop throughout its life cycle. It is the most crucial factor in determining the crop's economic worth when evaluating the effectiveness of various treatments. The gobhi sarson seed yield statistics are displayed in Table. 7 and Fig. 7., which revealed that seed yield increased significantly with 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4. Maximum seed yield of 19.7 q ha-1 was obtained with the application of 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 and it was significantly higher than all other treatments. The increased seed yield in treatment T9 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 suggests that the balanced nutrient supply positively influenced crop growth and reproductive success. Nitrogen, provided by urea, is known to enhance vegetative growth and reproductive processes, leading to increased seed set and yield. Additionally, the presence of micronutrients such as iron and zinc may have played a role in improving overall plant health and stress tolerance, contributing to higher yields. Previous studies, such Kaur *et al.,* [19], Sidhu *et al.,* [20] have reported the similar results.

3.11 Biological Yield (q/ha)

The treatment with T1 (RDF Control) shows the lowest biological yield (86.5) q/ha. The treatment with T9 (75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4) significantly shows the higher biological yield (100.4) q/ha presented in Table 8 and Fig. 8. From the data we can clearly shows that 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows maximum biological yield than RDF control. that 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, which was statistically par with 50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, but statistically higher than other treatments.

Table 7. Seed yield, No. of seeds/ siliquae, Test weight

Treatments	seed yield	No. of seeds/ siliquae	Test weight
100% RDF (Control)	17.4	17.2	4.62
50%RDF + 1% Urea	18.1	18.2	4.82
50% RDF + 0.5% FeSO4	17.7	17.5	4.73
50% RDF + 0.5% ZnSO4	18.2	18.1	4.76
50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	19	18.7	4.98
75%RDF +1% Urea	18.2	18.4	4.85
75% RDF + 0.5% ZnSO4	18	17.7	4.76
75%RDF + 0.5% FeSO4	18.2	18.2	4.79
75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	19.7	19.1	5.07
S. Em (±)	0.20	0.15	0.02
C.D. @ 5%	0.60	12.4	0.06

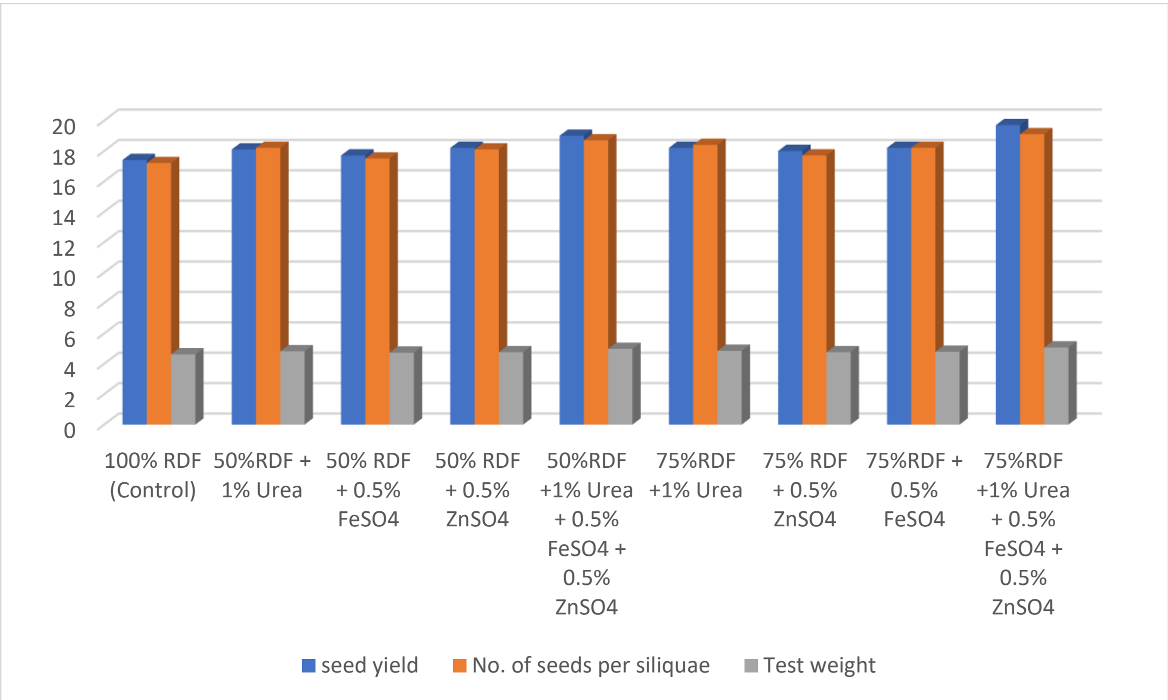

Fig. 7. Seed yield, No. of siliquae, test weight

Table 8. Biological yield

Treatments	Biological yield q/ha
100% RDF (Control)	86.5
50%RDF + 1% Urea	91.3
50% RDF + 0.5% FeSO4	90.9
50% RDF + 0.5% ZnSO4	92.7
50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	97.7
75%RDF +1% Urea	92.3
75% RDF + 0.5% ZnSO4	92.5
75%RDF + 0.5% FeSO4	93.6
75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	100.4
S. Em (±)	0.64
C.D. @ 5%	1.92

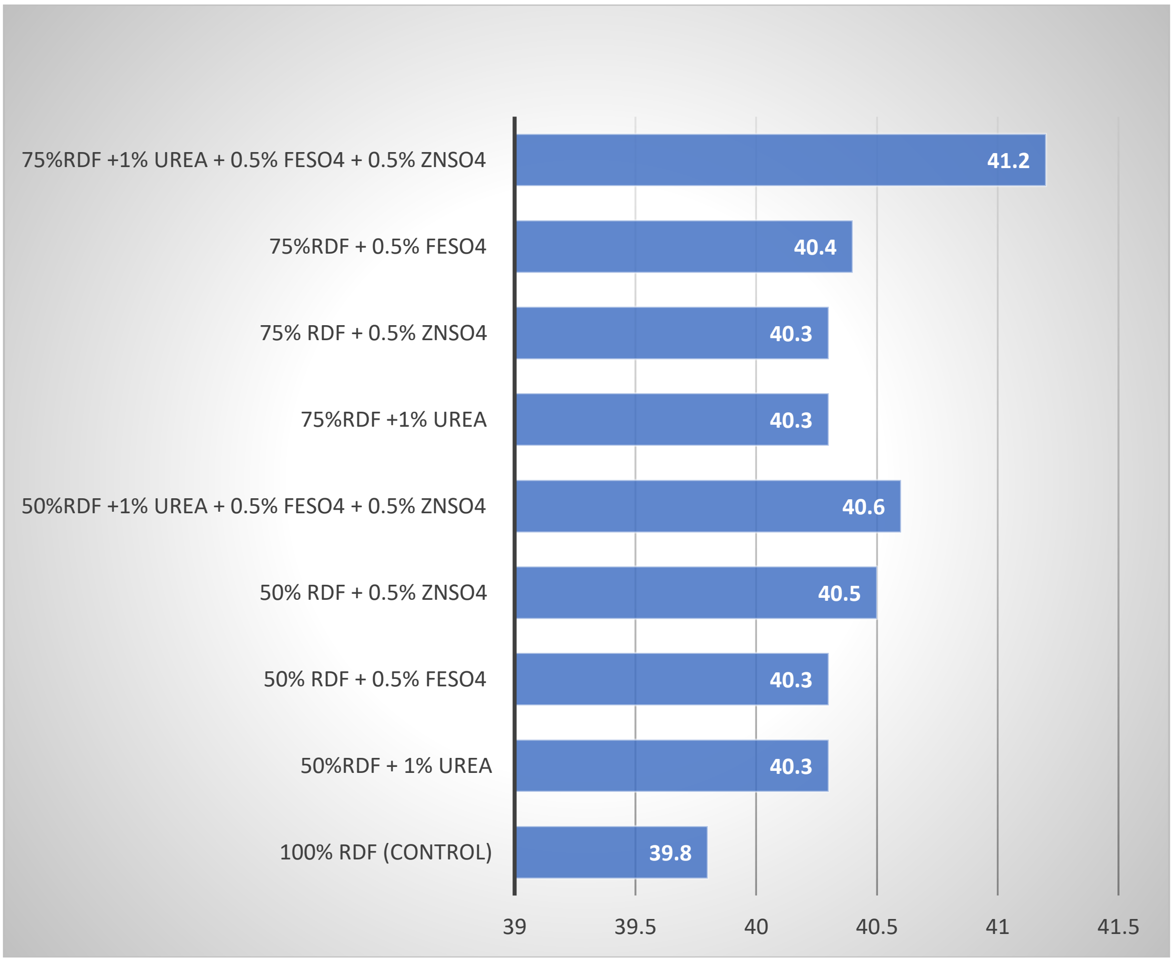

Fig. 8. Biological yield q/ha

3.12 Oil Content (%)

Data pertaining to oil yield at harvest as influenced by different weed management practices are presented in Table 9 and graphically depicted in Fig. 9. The treatment with 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 shows the highest oil content (41.2%). The treatment with RDF Control significantly shows the lower oil content (39.8%) and that 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, which was statistically par with 50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4, but statistically higher than other treatments. Mehara *et al.*, [21], Pavithra *et al.*, [22] has reported the similar results.

Table 9. Oil content (%)

Treatments	Oil content (%)
100% RDF (Control)	39.8
50%RDF + 1% Urea	40.3
50% RDF + 0.5% FeSO4	40.3
50% RDF + 0.5% ZnSO4	40.5
50%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	40.6
75%RDF +1% Urea	40.3
75% RDF + 0.5% ZnSO4	40.3
75%RDF + 0.5% FeSO4	40.4
75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZnSO4	41.2
S. Em (±)	0.24
C.D. @ 5%	0.73

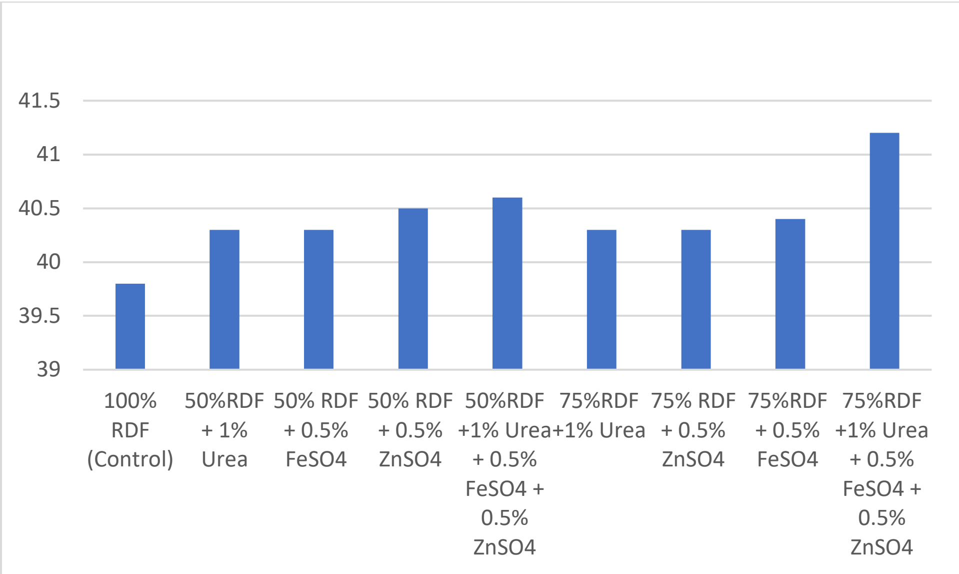

Fig. 9. Oil content (%)

3. CONCLUSION

The results showed that the foliar spray of 75% RDF + 1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 (T9) improved growth and yield metrics and performed well. Recorded were the maximum seed production, Oil content, gross returns, net returns when 75% RDF + 1% Urea + 0.5% FeSO4 + 0.5% ZnSO4 were applied (T9). Since these results are based on a single season, more research may be necessary to provide more assurance.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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