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Effect of fertility levels on growth and quality parameters of linseed (*Linum usitatissimum* L.) under different irrigation levels

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Abstract

A field experiment was conducted during 2024-25 at Agronomy Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan to evaluate the “Effect of fertility levels on growth, yield and quality of linseed (*Linum usitatissimum* L.) under different irrigation levels. The experiment was laid out in split plot design with three replications. The experiment comprised four levels of irrigation viz.; control, one irrigation, two irrigation and three irrigation as main plot and three levels of fertility viz; 50% RDF, 75% RDF and 100% RDF as sub plot. The significantly higher growth parameters viz., plant height, number of branches, dry matter accumulation (DMA), crop growth rate (CGR) and relative growth rate (RGR) and quality parameters i.e. the maximum oil content and oil yield (501.68 kg ha⁻¹), protein content and yield (287.16 kg ha⁻¹) and maximum N, P, K and S content and their uptake by linseed were obtained with the application of three irrigation followed by two irrigations. However, Among the fertility level, the application of 100% RDF gave significantly higher growth parameters viz., plant height, number of branches plant⁻¹, DMA, CGR and RGR and quality parameters i.e. the maximum oil content and oil yield (437.66 kg ha⁻¹), protein content and yield (232.54 kg ha⁻¹) and maximum N, P, K and S content and their uptake by linseed and it was followed by 75% RDF.

Keywords: Linseed, irrigation, fertility, growth, quality, nutrient content and uptake

Introduction

In India, oilseeds hold a significant position in agriculture, ranking next to cereals in importance. The country represents the world's third-largest edible oil economy after the United States and China and stands as the second-largest importer after China. Linseed (*Linum usitatissimum* L.) is cultivated across approximately 4.53 million hectares worldwide, producing about 3.97 million tonnes, with an average global yield of 991 kg ha⁻¹. Major linseed-producing countries include India, Canada, Russia, China, the United States, Kazakhstan, and Ethiopia, with Russia recording the highest productivity. India ranks third globally in area under linseed cultivation, contributing around 23.8% of the total acreage, and sixth in total production with about 10.2% of global output. In India, linseed is cultivated over an area of nearly 1.7 lakh hectares, producing around 1.0 lakh tonnes, with an average productivity of 574 kg ha⁻¹. The major linseed-growing states are Jammu and Kashmir, Madhya Pradesh, Chhattisgarh, Jharkhand, Bihar, Uttar Pradesh, and Maharashtra, with Jammu and Kashmir achieving the highest productivity of 2478 kg ha⁻¹ (DES, 2023) ^[1].

Linseed is a significant oilseed as well as a fiber crop, valued for its wide industrial applications. The fiber obtained from linseed is utilized in the manufacture of cloth, canvas, water-resistant pipes, packaging materials, plastic reinforcement, and as an eco-friendly substitute for fiberglass. The oil extracted from linseed serves as an excellent drying agent and is extensively used in the production of varnishes, paints, printing inks, high-grade soaps, oil colors, and in wood treatment, building, and construction industries (Ahlawat and Gangaiah, 2010) ^[2]. Moreover, linseed oil is nutritionally important as it is rich in Omega-3 fatty acids. It can also be used as an edible oil, particularly when the linolenic acid content is reduced to below 3 percent,

making it suitable for culinary purposes (Sharma *et al.*, 2012) [3]. Among various agronomic practices that enhance crop productivity, the availability of adequate moisture plays a crucial role. In rainfed regions, fluctuations in both the amount and distribution of rainfall significantly affect crop yield. Out of the total cultivated area of 143 million hectares in India, nearly 101 million hectares (around 70%) are dependent on rainfall for crop production (Kumar and Kumawat, 2014) [4]. Linseed shows a positive response to supplemental irrigation, which helps increase biomass production per unit area due to enhanced foliage development and higher transpiration rates. The beneficial impact of irrigation on linseed highlights the importance of providing additional water during critical growth stages that are highly susceptible to moisture stress (Singh *et al.*, 2010) [5].

The decline in soil fertility is one of the primary factors responsible for the low productivity of cultivated lands. Traditionally, efforts to improve soil health have mainly focused on supplementing it with major nutrients such as nitrogen (N), phosphorus (P), potassium (K), and sulphur (S). Nitrogen is a vital component of proteins, enzymes, and chlorophyll, and it plays a key role in protoplasmic activities, enzymatic reactions, and photosynthesis. It is crucial for early leaf development, enhancing photosynthetic activity, and promoting root growth, which together contribute to better water-use efficiency (Homayouni *et al.*, 2013) [6]. Phosphorus application improves seed quality and supports essential physiological processes like photosynthesis, respiration, protein and lipid synthesis, and sugar formation. It also plays an important role in energy transfer through molecules such as Adenosine Triphosphate (ATP) and Nicotinamide Adenine Dinucleotide Phosphate (NADPH). Moreover, phosphorus and potassium utilization becomes more efficient when nitrogen is adequately available (Kumar and Deka, 2016) [7]. Sulphur is another essential nutrient involved in several physiological functions, including the synthesis of amino acids such as cysteine and methionine, as well as chlorophyll and oil formation in oilseed crops. Since sulphur forms a key component of linseed oil, its deficiency can lead to a marked decline in both yield and oil content. Therefore, ensuring a balanced and sufficient supply of plant nutrients is vital for enhancing the productivity and quality of oilseed crops (Singh *et al.*, 2013) [8].

Among the various ingredients of crop production, irrigation and fertility levels are of immense importance and therefore need special attention to exploit full yield potential of linseed. However, scientific data on these aspects are very meagre. Keeping these facts in view, the present field trial was conducted.

Materials and Methods

The field experiment was carried out at the Agronomy Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan during rabi season of 2024-25. The experimental site is situated in semi-arid eastern plains of Rajasthan and lies between 26°92' North latitude, 75°78' East longitude and at an altitude of 430 meters from the mean sea level. The soil of the experimental field was sandy in texture and slightly alkaline in reaction with PH 7.58, organic carbon (OC) (0.43%), available nutrient (N 217.30; phosphorus (P) 20.28, potassium (K) 219.20 kg ha⁻¹ and sulphur 20.90 mg kg⁻¹). The experiment was laid out in split plot design with three replications. The field trial consists four irrigation levels in main plot viz., (i) control, (ii) one irrigation, (iii) two irrigations, (iv) three irrigation and three fertility levels in sub plot viz., (i) 50%

RDF, (ii) 75% RDF and (iii) 100% RDF. The linseed variety "Shekhar" was sown @ 30 kg seed ha⁻¹ with spacing of 30 cm x 10 cm. All agricultural practices were kept uniform in all the plots.

Results and Discussion

Growth Parameters

Effect of irrigation levels

The different irrigation levels significantly enhanced the growth parameters viz. plant height (cm) and DMA (g plant⁻¹) at 30, 60, 90 DAS and at harvest, number of branches plant⁻¹ at 60, 90 DAS and at harvest, CGR (g plant⁻¹ day⁻¹) and RGR (g g⁻¹ day⁻¹) at 30-60 DAS and 60-90 DAS of the linseed (Table 1). The significantly maximum plant height (8.90 cm at 30 DAS; 29.80 cm at 60 DAS; 56.20 cm at 90 DAS and 57.45 cm at harvest), number of branches plant⁻¹ (6.80 at 60 DAS; 13.60 at 90 DAS and 13.94 at harvest), DMA (0.175 g plant⁻¹ at 30 DAS; 3.70 g plant⁻¹ at 60 DAS; 7.72 g plant⁻¹ at 90 DAS and 7.90 g plant⁻¹ at harvest), CGR (0.117 g plant⁻¹ day⁻¹ at 30-60 DAS and 0.134 g plant⁻¹ day⁻¹ at 60-90 DAS) and RGR (0.0510 g g⁻¹ day⁻¹ at 30-60 DAS and 0.0583 g g⁻¹ day⁻¹ at 60-90 DAS) The maximum values were observed with the application of three irrigations, which were statistically at par with those obtained under two irrigations. This may be attributed to the crucial role of soil moisture in facilitating the movement and distribution of nutrients within the soil and their subsequent uptake by plants. Adequate soil water also helps maintain the osmotic balance in plant cells. These observations clearly highlight the significance of sufficient water availability for supporting optimal metabolic activities, which ultimately enhances plant growth and development. The significant improvement in growth parameters with increasing irrigation levels could be due to intensified cellular activities, leading to enhanced apical growth and accelerated elongation of internodes. Similar, profuse branching under irrigated environment could be ascribed to formation of higher lateral buds and later on adequate supply of metabolites and nutrient might have helped their proper growth and development. The present result is in close conformity with Chauhan *et al.* (2008) [9], Ahlawat and Gangaiah (2010) [2], Mirshekari *et al.* (2012) [10], Bassegio *et al.* (2013) [11], and Devedee *et al.* (2019) [12].

Effect of fertility levels

The different irrigation levels significantly enhanced the growth parameters viz. plant height (cm) and DMA (g plant⁻¹) at 30, 60, 90 DAS and at harvest, number of branches plant⁻¹ at 60, 90 DAS and at harvest, CGR (g plant⁻¹ day⁻¹) and RGR (g g⁻¹ day⁻¹) at 30-60 DAS and 60-90 DAS of the linseed (Table 1). The significantly maximum plant height (7.81 cm at 30 DAS; 26.16 cm at 60 DAS; 50.58 cm at 90 DAS and 51.97 cm at harvest), number of branches plant⁻¹ (6.15 at 60 DAS; 12.31 at 90 DAS and 12.61 at harvest), DMA (0.158 g plant⁻¹ at 30 DAS; 3.35 g plant⁻¹ at 60 DAS; 6.99 g plant⁻¹ at 90 DAS and 7.14 g plant⁻¹ at harvest), CGR (0.106 g plant⁻¹ day⁻¹ at 30-60 DAS and 0.121 g plant⁻¹ day⁻¹ at 60-90 DAS) and RGR (0.0462 g g⁻¹ day⁻¹ at 30-60 DAS and 0.0527 g g⁻¹ day⁻¹ at 60-90 DAS) The highest values were obtained with the application of 100% RDF, which were statistically comparable to those achieved with 75% RDF. An adequate and balanced supply of plant nutrients plays a crucial role in enhancing the growth parameters of oilseed crops. Linseed showed a significant response to fertilizer application, which varied according to soil type and nutrient source. The functions of essential nutrients within plants are directly linked to their growth and developmental processes. The increased

availability of nitrogen, phosphorus, and potassium in the soil promoted vigorous vegetative growth, enabling plants to reach their full potential in terms of plant height, number of branches per plant, dry matter accumulation, crop growth rate (CGR), relative growth rate (RGR), leaf area, and photosynthetic activity. Similar findings were also reported by Ekebafe *et al.* (2011) [13], Singh *et al.* (2010) [14], and Patil *et al.* (2018) [15].

Quality Parameters

Effect of irrigation levels

The different levels of irrigation significantly enhanced the quality parameters viz., oil and protein content (%) and their yield (kg ha⁻¹) of the linseed crop (Table 4.2). The maximum oil content (39.85%) and oil yield (501.68 kg ha⁻¹) protein content (22.76%) and protein yield (287.16 kg ha⁻¹) were recorded with the application of three irrigation and it was statistically at par with the application of two irrigation. The increase in oil content might be due to reduced irrigation intervals enhancing the protein accumulation. Further oil production which is a function of seed yield and oil content in seed recorded similar increase with increasing application of irrigation. Almost similar findings were also reported by Kumar and Singh (2008) [16], Patil *et al.* (2012) [17] and Patel *et al.* (2017) [18]. Moreover, the different levels of irrigation significantly enhanced the nutrient content and their uptake viz. N, P, K and S content (%) and their uptake (kg ha⁻¹) in grain and straw of the linseed crop (Table 3). The maximum nutrient content (N 3.64 in grain and 0.750 in straw; P 0.800 in grain and 0.140 in straw; K 0.720 in grain and 0.880 in straw and S 0.380 in grain and 0.190 in straw) and their uptake (N 45.95 by grain and 16.42 by straw; P 10.09 by grain and 3.05 by straw; K 9.08 by grain and 19.26 by straw; S 4.79 by grain and 4.16 by straw) were recorded with the application of three irrigation and it was statistically at par with the application of two irrigation. On one hand the improvement in soil water status through irrigation increases the solubility and degree of ionization of nutrients in the soil which in turn increases availability of nutrients. While on the other hand, soil water exerts profound influence on the capacity of roots to absorb nutrients efficiently and their transportation (longitudinal and radial transport) in plant system. In this context it is well established fact that increase in soil moisture tension (low soil moisture status) exerts a physiological effect on roots, i.e. their elongation, turgidity and number of root hairs is are reduced further under these situations (Sharma *et al.*, 2012) [3]. similar findings were also reported by Omidbaigi *et al.* (2001) [19] Khokhar *et al.* (2005) [20], Kumar and Singh (2008) [13] and

Mirshekari *et al.* (2012) [10].

Effect of fertility levels

The different levels of irrigation significantly enhanced the quality parameters viz., oil and protein content (%) and their yield (kg ha⁻¹) of the linseed crop (Table 2). The maximum oil content (39.54%) and oil yield (437.66 kg ha⁻¹) protein content (20.59%) and protein yield (232.54 kg ha⁻¹) were recorded with the application of 100% RDF and it was statistically at par with the application of 75% RDF. This may be attributed to the fact that increasing the rate of nitrogen fertilizer application had a significant positive effect on the protein content of linseed seeds. Since nitrogen is a fundamental component of proteins, higher fertilizer application rates often result in increased protein accumulation. Several researchers have reported that nitrogen fertilization enhances protein content, though often at the expense of oil content. Generally, there exists an inverse relationship between protein and oil content—an increase in one typically leads to a decrease in the other. Protein yield is determined by both seed yield and protein concentration. These discoveries are in agreement with those of Sune *et al.* (2006) [21], Verma *et al.* (2009) [22] and Singh *et al.* (2013) [8].

Moreover, the different levels of irrigation significantly enhanced the nutrient content and their uptake viz. N, P, K and S content (%) and their uptake (kg ha⁻¹) in grain and straw of the linseed crop (Table 3). The maximum nutrient content (N 3.30 in grain and 0.679 in straw; P 0.724 in grain and 0.126 in straw; K 0.651 in grain and 0.797 in straw and S 0.344 in grain and 0.172 in straw) and their uptake (N 37.21 by grain and 13.23 by straw; P 8.17 by grain and 2.46 by straw; K 7.35 by grain and 15.53 by straw; S 3.88 by grain and 3.35 by straw) were recorded with the application of 100% RDF and it was statistically at par with the application of 75% RDF. The graded application of different fertility levels consistently enhanced the content and uptake of N, P, K, and S by the crop. The potassium content was comparatively higher, which may be attributed to the increased nutrient supply and its greater availability to plants, leading to luxury consumption—particularly in the case of potassium. Nitrogen, phosphorus, and sulphur are primarily utilized in processes related to oil synthesis and dry matter accumulation; therefore, their concentration in straw and seed increased to a lesser extent compared to potassium. Similar findings have been reported by Anupama *et al.* (2007) [23], Singh *et al.* (2010) [13], Awasthi *et al.* (2011) [24], Singh *et al.* (2013) [8], and Kumar (2017) [25].

Table 1: Effect of irrigation and fertility levels on growth parameters of linseed at different growth stages

Treatments	Plant height (cm)				Number of branches plant ⁻¹			DMA (g plant ⁻¹)				CGR (g plant ⁻¹ day ⁻¹)		RGR (g g ⁻¹ day ⁻¹)	
	30 DAS	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
Irrigation Levels															
Zero irrigation	5.07	16.96	36.99	38.72	4.58	9.17	9.39	0.118	2.49	5.21	5.32	0.079	0.090	0.0344	0.0393
One irrigation	6.82	22.82	43.03	44.62	5.28	10.56	10.82	0.136	2.87	6.00	6.13	0.091	0.104	0.0396	0.0453
Two irrigation	8.67	29.04	54.76	56.05	6.63	13.27	13.60	0.171	3.61	7.54	7.70	0.115	0.131	0.0498	0.0568
Three irrigation	8.90	29.80	56.20	57.45	6.80	13.60	13.94	0.175	3.70	7.72	7.90	0.117	0.134	0.0510	0.0583
S.Em±	0.15	0.49	0.93	0.90	0.11	0.21	0.22	0.003	0.06	0.12	0.12	0.002	0.002	0.0008	0.0009
CD (p=0.05)	0.51	1.70	3.21	3.13	0.37	0.74	0.76	0.010	0.20	0.42	0.43	0.006	0.007	0.0028	0.0032
Fertility Levels															
50% RDF	6.73	22.53	43.74	45.31	5.36	10.73	10.99	0.138	2.92	6.09	6.23	0.093	0.106	0.0402	0.0460
75% RDF	7.55	25.28	48.91	50.35	5.96	11.92	12.21	0.153	3.24	6.77	6.92	0.103	0.118	0.0447	0.0511
100% RDF	7.81	26.16	50.58	51.97	6.15	12.31	12.61	0.158	3.35	6.99	7.14	0.106	0.121	0.0462	0.0527
S.Em±	0.09	0.32	0.60	0.58	0.07	0.14	0.14	0.002	0.04	0.08	0.08	0.001	0.001	0.0005	0.0006
CD (p=0.05)	0.28	0.95	1.79	1.75	0.21	0.41	0.42	0.005	0.11	0.23	0.24	0.004	0.004	0.0016	0.0018

Table 2: Effect of irrigation and fertility levels on quality parameters of linseed crop

Treatments	Quality parameters			
	Oil content (%)	Oil yield (kg ha ⁻¹)	Protein content (%)	Protein yield (kg ha ⁻¹)
Irrigation Levels				
Zero irrigation	33.85	234.10	15.35	106.33
One irrigation	37.61	358.54	17.68	168.63
Two irrigation	38.87	475.55	22.21	271.70
Three irrigation	39.85	501.68	22.76	287.16
S.Em±	0.30	21.52	0.36	9.75
CD (p=0.05)	1.04	74.47	1.24	33.76
Fertility Levels				
50% RDF	34.67	329.45	17.96	175.18
75% RDF	38.42	410.28	19.95	217.64
100% RDF	39.54	437.66	20.59	232.54
S.Em±	0.33	12.25	0.23	5.01
CD (p=0.05)	0.99	36.73	0.69	15.03

Table 2: Effect of irrigation and fertility levels on nutrient content and their uptake by linseed crop

Treatments	N content (%)		N uptake (kg ha ⁻¹)		P content (%)		P uptake (kg ha ⁻¹)		K content (%)		K uptake (kg ha ⁻¹)		S content (%)		S uptake (kg ha ⁻¹)	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
Irrigation Levels																
Zero irrigation	2.46	0.506	17.01	7.06	0.539	0.094	3.74	1.31	0.485	0.594	3.36	8.28	0.257	0.128	1.78	1.79
One irrigation	2.83	0.583	26.98	9.84	0.621	0.108	5.93	1.83	0.559	0.684	5.33	11.54	0.296	0.148	2.82	2.49
Two irrigation	3.55	0.732	43.47	15.26	0.781	0.136	9.55	2.84	0.702	0.859	8.59	17.90	0.371	0.186	4.53	3.87
Three irrigation	3.64	0.750	45.95	16.42	0.800	0.140	10.09	3.05	0.720	0.880	9.08	19.26	0.380	0.190	4.79	4.16
S.Em±	0.06	0.012	1.84	0.50	0.013	0.002	0.34	0.09	0.011	0.014	0.31	0.59	0.006	0.003	0.16	0.13
CD (p=0.05)	0.20	0.041	6.38	1.74	0.044	0.008	1.19	0.32	0.039	0.048	1.07	2.05	0.020	0.010	0.56	0.44
Fertility Levels																
50% RDF	2.87	0.592	28.03	10.64	0.631	0.110	6.16	1.98	0.568	0.694	5.54	12.48	0.300	0.150	2.93	2.70
75% RDF	3.19	0.658	34.82	12.56	0.701	0.122	7.65	2.33	0.631	0.772	6.88	14.74	0.333	0.167	3.63	3.18
100% RDF	3.30	0.679	37.21	13.23	0.724	0.126	8.17	2.46	0.651	0.797	7.35	15.53	0.344	0.172	3.88	3.35
S.Em±	0.04	0.008	0.90	0.25	0.008	0.001	0.18	0.05	0.007	0.009	0.16	0.29	0.004	0.002	0.08	0.06
CD (p=0.05)	0.11	0.023	2.70	0.75	0.024	0.004	0.53	0.14	0.022	0.027	0.48	0.88	0.011	0.006	0.25	0.19

Conclusion

Based on the findings of a one-year field experiment on linseed, it can be concluded that the combined application of three irrigations along with 100% RDF proved most effective in enhancing growth parameters, yield attributes, yield, quality, nutrient content, and nutrient uptake. This treatment was closely followed by the application of two irrigations with 75% RDF. Moreover, the combination of three irrigations and 100% RDF also resulted in the highest net returns and benefit-cost (B:C) ratio, followed by two irrigations with 75% RDF.

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