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Studies on the impact of iron and zinc nutrition on growth and quality of linseed (*Linum usitatissimum* L.)

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Abstract
A field experiment was conducted at College of Agriculture, Vijayapura during *rabi* season, 2020-21 to study the effect of iron and zinc nutrition on growth and quality of linseed as the iron and zinc content in the soil at College of Agriculture is below the critical limit. The experiment was laid out in randomized complete block design with ten treatments and three replications. The treatments included RPP (Recommended package of practices) and application of ferrous sulphate @ 5, 10 and 15 kg ha^{-1} and zinc sulphate @ 5, 10 and 15 kg ha^{-1} in various combinations along with RPP (Recommended package of practices @ 40:20:20:3000-N:P_2O_5:K_2O:FYM kg ha^{-1}). The results of the experiment revealed that, the application of iron and zinc in combinations resulted in significant increase in growth and quality of linseed as compared to RPP alone. Among the different treatments combination RPP + 15 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1} was resulted in the maximum plant height at flowering (46.5cm) and at harvest (49.1), dry matter accumulation (5.08 g plant^{-1}), number of branches per plant (5.40), number of capsules per plant (59.0) and number of seeds per capsule (5.97) and higher oil content (40.3%) and protein content of linseed (20.6%) were recorded. These results were on par with the application of RPP + 15 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} and lower values were recorded in the treatment that received RPP alone. Finally it could be concluded that the application of fertilizers containing iron and zinc helps to improve crop growth, oil and protein content in linseed crop.

Keywords: Linseed, iron, oil and protein content, zinc

Introduction
Oil seeds play a significant role in the day-to-day life of the people. Oil seeds are very important component of tropical agriculture as they provide easily available and highly nutritious food to human beings and animals. India has highly developed oil based industry providing employment to more than 15 million people. Apart from providing much required calories to the population, oil seeds also act as life line to the age old milling industry. Oil seeds provide the much needed protein and energy to the people as well as to the large livestock population of the country.
Linseed or Flaxseed (*Linum usitatissimum* L.) is blue flowering *rabi* crop and a member of family Linaceae, which is cultivated for its seeds, oil and fibres. Seeds of linseed have the medicinal importance as it contains linolenic acid, omega-3 fatty acid, protein and dietary fibre. Linseed dietary fibre exhibits positive effects to reduce constipation. The seeds of linseed contain 32 to 46 per cent of oil and it is a drying oil, the oil cake contains 10 per cent oil, 11 per cent moisture, 32 per cent protein, 6 per cent minerals and 9 per cent fibres (Prasad, 2018) [12]. In India, flaxseed is grown mainly in the central part of the country, like Madhya Pradesh, eastern Maharashtra, Bihar and Uttar Pradesh. It occupies an area of about 2.62 lakh hectare with an annual production of 1.25 lakh tonnes and productivity of 477 kilograms per hectare. However, it occupies an area five thousand hectares in Karnataka with production of 1460 tonnes and productivity of 293 kilograms per hectare. India place first in area, fourth in production and eighth in productivity. Madhya Pradesh ranks first in area and production among the flaxseed cultivating states of India (Anon, 2016) [3].
Iron and zinc are essential for plants as well as humans and animals who consume plant produce. Iron is needed in the greatest quantity and its availability is dependent on the pH of the growing

medium. Fe is absorbed through plant roots in form of Fe^{++} and Fe^{+++}. It is an essential constituent of catalase, peroxidase and cytochrome oxidase. Iron is also a part of protein ferredoxin which is required in nitrate and sulphate reduction (Marschner and Rengel, 2012) [9]. Zn is absorbed through plant roots as the Zn^{++} cation and is involved in production of chlorophyll, protein, and several plant enzymes involved in growth regulation. Zinc is involved in auxin formation; activation of dehydrogenase enzymes; stabilization of ribosomal fractions in oilseed crop. An increase in energy values as well as total lipids and crude protein in oilseed crop was registered with Zn application (Nayyar *et al.* 1990) [10].

The deficiency of Fe and Zn is observed in most of the soils of northern dry zone of Karnataka. It is necessary for agricultural systems to ensure proper products, which will balance the quantity of nutrients to support, the healthy living. Hence, this experiment was carried out on the studies on the effect of iron and zinc nutrition on quality and yield of linseed.

Materials and Methods

A field experiment was conducted to study the effect of iron and zinc nutrition on growth and quality of linseed at College of Agriculture, Vijayapura during *rabi* season, 2020-21 under Northern Dry Zone of Karnataka (Zone 3), situated at 16°49' N latitude and 75°43' E longitude and at an altitude of 593.8 m above the mean sea level. The soil is black in colour and clay in texture with 25.5, 15.3 and 59.2 per cent sand, silt and clay, respectively. The soil is alkaline in reaction (pH 8.33) and low in soluble salts (0.38 dS m^{-1}). The soil was low in organic carbon (3.40 g kg^{-1}) and available nitrogen (208 kg ha^{-1}) and medium in available P (11.8 kg ha^{-1}), while it was high in K (348 kg ha^{-1}) and sulphur (15.11 kg ha^{-1}). The free calcium carbonate content was 13.40 per cent. The DTPA extractable micronutrient content *viz*., zinc, iron, copper and manganese were 0.40, 2.40, 0.68 and 6.00 mg kg^{-1}, respectively. The content of Zn and Fe in soil was below the critical limit.

The experiment was laid out in randomized complete block design with ten treatments and three replications including RPP, application of iron @ 5, 10, 15 kg ha^{-1} and zinc @ 5, 10, 15 kg ha^{-1} in combinations. RPP @ 40:20:20:3000- N: P_2O_5:K_2O: FYM kg ha^{-1} was applied to all the treatments. Fe and Zn were applied through $FeSO_4$. $7H_2O$ (19%Fe) and $ZnSO_4$. $7H_2O$ (21%Zn), respectively. FeSO4. 7H2O and ZnSO4. 7H2O were chelated with vermicompost at 1:1 ratio for 15 days before sowing. Treatments included were, T_1: Recommended package of practices (RPP), T_2: RPP + 5 kg $FeSO_4$ ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}, T_3: RPP + 5 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}, T_4: RPP + 5 kg $FeSO_4$ ha^{-1}+ 15 kg $ZnSO_4$ ha^{-1}, T_5: RPP + 10 kg $FeSO_4$ ha^{-1}+ 5 kg $ZnSO_4$ ha^{-1}, T_6: RPP + 10 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}, T_7: RPP + 10 kg $FeSO_4$ ha^{-1}+ 15 kg $ZnSO_4$ ha^{-1}, T_8: RPP + 15 kg $FeSO_4$ ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}, T_9: RPP + 15 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1} and T_{10}: RPP + 15 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}. After the onset of monsoon seeds were sown in the plot at the spacing of 45 cm × 10 cm. Then the thinning and gap filling operations were done at the right time to maintain optimum plant population.

Recommended dose of nitrogen (40 kg N ha^{-1}), phosphorus (20 kg P_2O_5 ha^{-1}) and potassium (20 kg K_2O ha^{-1}) were applied through urea, DAP and MOP. The entire quantity of fertilizer was applied as basal dose. The observations recorded was plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, dry matter accumulation, Oil content in linseed seeds was estimated by NMR method and protein content was calculated by multiplying the nitrogen content with factor 6.25. The data collected from the experiment during crop growth period were subjected to statistical analysis as described by Gomez and Gomez (1984) [6].

Results and Discussion

Growth attributes

Significantly highest plant height at flowering (46.5 cm), after harvest stage (49.1 cm) and dry matter accumulation (5.08 g $plant^{-1}$) compared to other treatments recorded in the treatment (T_{10}) which received RDF + 15 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}. The lower plant height at flowering (28.2 cm), after harvest stage (31.2 cm) and dry matter accumulation (3.06 g $plant^{-1}$) was recorded in the treatment (T_1) which received RPP only (Table 1). The increase in the plant height in linseed was due to enhancement of auxin biosynthesis and synergistic relationship between zinc and nitrogen which leads to vigorous growth, and higher photosynthesis, a balanced supply of plant nutrients through soil application along with FYM, RDF and IAA production which helps in promoting plant growth. The increase in the dry matter accumulation was due to availability of these micronutrients to the crop at appropriate vegetative stage, which might have increased the nutrient uptake and chlorophyll content and might improve photosynthetic area of plants that cumulatively contribute to higher dry matter accumulation and iron act as a catalyst in chlorophyll formation and improves the photosynthesis process, leading to more dry matter production. Anchal *et al*. (2020) [2] reported that application of iron increased the plant height in linseed. Similar findings reported by Raghavendra *et al*. (2020) [13] in sunflower and Parwaiz *et al*. (2021) [11] in linseed. Singh *et al*. (2017) [15] reported that application of zinc at 30 kg per hectare resulted in higher dry matter accumulation in soybean and Ravi *et al*. (2008) [14] reported the same in safflower.

Significantly higher number of branches per plant (5.40), number of capsules per plant(59.0) and number of seeds per capsule (5.97) was recorded in treatment (T_{10}) which received RPP + 15 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}. The lower number of branches per plant (3.10), number of capsules per plant (53.2) and number of seeds per capsule (4.17) was recorded in the treatment (T_1) which received RPP only (Table 2). Higher number of branches per plant is attributed to increase in absorption and translocation of assimilation and stimulation graphical and lateral meristems grow. These two micronutrients especially iron activate several enzymes (catalase peroxidase, alcohol, dehydrogenase, carbonic dehydrogenize, tryptophan synthates *etc*) and involved themselves in chlorophyll synthesis and various physiological activities by which number of braches per plant increases and increase in number of capsules might be due various levels of zinc application due to its role in cofactor enzyme, involvement in pollen function, fertilization, chlorophyll production and increased photosynthesis. Combined application of these two micronutrients (Fe and Zn) to soil which might have increased the nutrient uptake and chlorophyll content and resulted in increased the number of seeds per capsule. The results in accordance with Kumar *et al*. (2014) [7] reported that application of RDF+ Zn @ 25 kg per acre as basal and Fe @25 kg per acre as basal increased the number of branches per plant in mustard crop. Similar findings witnessed by Anchal *et al*. (2020) [2] in linseed. Ahmad *et al*. (2019) [16] reported that foliar application of 2.0% zinc sulphate increased the number of capsules per plant.

Quality parameters

The application of different levels of iron and zinc did not significantly increased oil content in linseed. However, higher oil content (40.3%) was noticed in the treatment (T_{10}) with RPP + 15 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1} but the lower oil content (35.4%) was found in the treatment (T_1) with RPP only (Fig 1). However, increase in oil content might be due higher oil content might be due to zinc and iron sulphate fertilization. That leads to proper functioning of many enzymes, involved in the formation of glycosides, glucosinolates and sulphydril-linkage, activation of enzymes which aids in biochemical reaction within the plant which helps in bio-synthesis of oil. Similar trend was also recorded by Malakooti *et al*. (2017) [8] in soybean and Ravi *et al*. (2008) [14] in safflower.

There is significant difference noticed in protein content of linseed due to application of iron and zinc. The lower protein content (19.5%) observed in treatment (T_1) which received RPP only. Significantly higher protein (20.6%) content was observed in the treatment (T_{10}) which received RPP+15 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}. Increase in protein content could be attributed to the fact that application of iron and zinc enriched with vermicompost increase the availability of N and S in soil their by increased uptake of N and S and helps in conversion of amino acids to protein and helps in translocation of nitrogen to grain so as a result increases protein content. Similar results were observed by Malakooti *et al*. (2017) [8], Singh *et al*. (2017) [15] and Vishal *et al*. (2019) [16].

Table 1: Effect of iron and zinc application on plant height and dry matter accumulation in linseed

Treatments	Plant height (cm)		Dry matter Accumulation (g $plant^{-1}$)
	At flowering stage	At harvest stage	After harvest stage
T_1: RPP*	28.2	31.2	3.06
T_2: RPP + 5 kg $FeSO_4$ ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}	29.6	32.6	3.43
T_3: RPP + 5 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}	31.4	33.4	3.59
T_4: RPP + 5 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	33.2	35.6	3.65
T_5: RPP + 10 kg $FeSO_4$ ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}	35.5	37.9	3.68
T_6: RPP + 10 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}	36.2	39.9	4.00
T_7: RPP + 10 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	38.6	42.8	4.19
T_8: RPP + 15 kg $FeSO_4$ ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}	40.1	43.1	4.35
T_9: RPP + 15 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}	45.0	48.2	4.78
T_{10}: RPP + 15 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	46.5	49.1	5.08
S.Em.(±)	0.97	1.33	0.12
C. D. (P = 0.05)	2.92	3.98	0.37

*RPP-Recommended package of practices

Table 2: Effect of iron and zinc application on number of branches per plant, number of capsules per plant and number of seeds per capsule in linseed.

Treatments	Number of branches/plant	Number of capsules/plant	Number of seeds/capsule
T_1: RPP*	3.10	53.2	4.17
T_2: RPP + 5 kg $FeSO_4$ ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}	3.57	53.6	4.70
T_3: RPP + 5 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}	3.80	53.9	4.83
T_4: RPP + 5 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	4.20	54.2	4.87
T_5: RPP + 10 kg $FeSO_4$ ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}	4.40	54.6	4.93
T_6: RPP + 10 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}	4.80	54.9	5.32
T_7: RPP + 10 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	5.03	55.1	5.66
T_8: RPP + 15 kg $FeSO_4$ ha^{-1} + 5 kg $ZnSO_4$ ha^{-1}	5.13	56.1	5.70
T_9: RPP + 15 kg $FeSO_4$ ha^{-1} + 10 kg $ZnSO_4$ ha^{-1}	5.33	58.6	5.93
T_{10}: RPP + 15 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	5.40	59.0	5.97
S.Em.(±)	0.05	0.66	0.06
C. D. (P = 0.05)	0.16	1.99	0.18

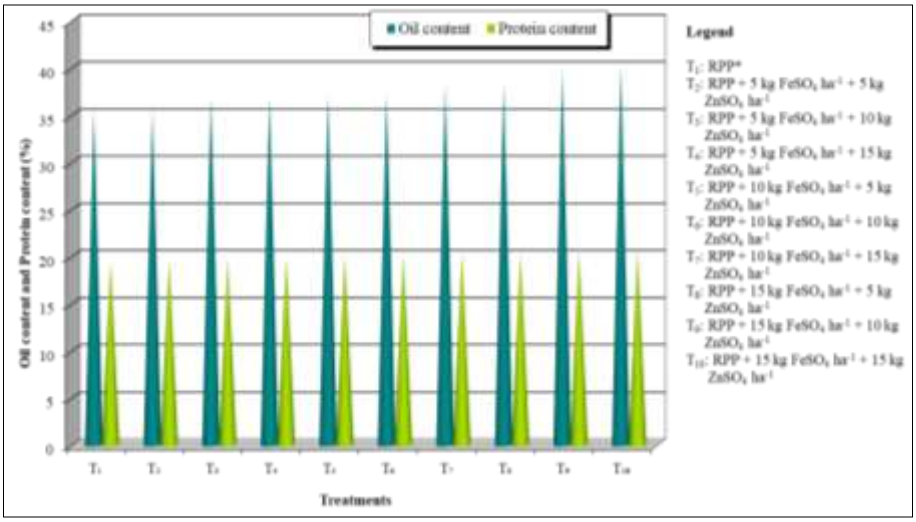

Fig 1: Oil content and protein content of linseed seeds as affected by application of iron and zinc to soil

Conclusion
Based on results of field experiment summarized that, the application of different levels of iron and zinc in combinations resulted in significant increase in growth parameters, oil and protein content over RPP alone in linseed. The significantly higher results were recorded in the treatment which received RDF + 15 kg $FeSO_4$ ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}. Therefore, it can be concluded that the application of fertilizers containing iron and zinc helps to increase crop growth attributes and also improves oil and protein content in linseed crop.

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