EFFECT OF FOLIAR APPLICATION OF ZINC ON YIELD AND OIL CONTENTS OF FLAX

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ABSTRACT:- The foliar application of micronutrients increases the yield and oil contents of flax. The present field study was conducted to find out the effect of foliar application of zinc on yield, yield components and oil contents of flax. The experiment was laid out in randomized complete block design with three replications. The 12 different zinc levels viz., control, 0.25%, 0.50%, 0.75%, 1.00%, 1.25%, 1.50%, 1.75%, 2.00%, 2.25%, 2.50%, 2.75% and 3.00% were applied by foliar spray at bud initiation and after capsule filling stage of flax. Zinc was used as a source of $ZnSO_4$. All the zinc treatments significantly improved plant height, stem length, fruiting zone length, fruiting branches, number of capsule plant^{-1}, number of seed capsule^{-1}, 1000-seed weight, straw yield, seed yield, and seed oil contents compared to control. Therefore, for producing a higher seed yield and oil contents of flax, it is suggested that 3.00% zinc at bud initiation and after capsule filling stage of flax should be used.

Key Words: Linum usitatissimum; Micronutrient Fertilizer; Zinc Sulphate; Application Rates; Spraying; Bud Initiation; Growth; Yields; Yield Components; Oil Contents; Pakistan.

INTRODUCTION

Flax (*Linum usitatissimum* L.) is an economically important oil and fiber crop (Maherani et al., 2007). Flax is rich in protein (20%), oil (41%) and dietary fiber (28%). The higher amount of linoleic acid and omega-3 fatty acid with amounts of 50-60% is also present in it (Hall et al., 2009). It has a great value for human because it is used as food and in paints and varnishes. In Pakistan, flax is cultivated in Punjab and Sindh provinces. It was cultivated on 4018 ha giving total production of 2779 kg ha^{-1} with an average yield of 692 kg ha^{-1} (GoP, 2010-11). The average yield of flax is very low in Pakistan due to many constraints like poor soil fertility, inadequate application of macro and micro nutrients, competition with other crops and traditional crop management practices. But among them nutrient imbalance appears to be the major reason (Ali et al., 2011). Due to constantly increasing demand of this crop, there is a dire need to increase seed yield potential of flax crop. Therefore, its production can be increased by growing high yielding cultivars and increasing the use of fertilizers (El-Shahawy et al., 2008). Micronutrients show a vital role in the enhancement of yield (Rehm and Sims, 2006). They are required in trace quantities, but their suitable stream increases the availability of other macro and micro nutrients and confidently affects the

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physiology of cell that is also revealed in yield (Adediran et al., 2004). Zinc is a trace mineral element required for normal growth of crops and deficiency of Zn severely affect the crops and reduces the yield (Gangloff et al., 2002).

The possibility for the deficiency of Zn is normally occurring in those soils which are low in organic matter and where the pH of soil is > 7. In such situations, Zn deficiency is corrected by the application of zinc fertilizers either by soil application, seed treatment or by foliar spray of those fertilizers having high amount of water soluble zinc (Cakmak, 2008). Now-a-days Zn fertilization is a common practice in agriculture, it is conceivable that, with the passage of time, soils which are zinc deficient will receive a lot of Zn to compensate its deficiency (Paschke et al., 2006). The deficiency of zinc is known as "chlorotic dieback". The plant gives pale color and its growing points become dead when Zn deficiency occurs. In later condition, sprouting starts from lower nodes, this is delayed due to Zn deficiency (Franzen, 2004). Flax plant is very vulnerable to the deficiency of zinc, mostly when the soil temperature is very low (Moraghan, 1980). This susceptibility is amplified by the application of phosphorus (Jiao et al., 2007). Grant et al. (2000) reported that different factors such as soil pH, environment, fertilizer management and cultivars are the biggest issues governing Zn uptake by flax. Several scientists have stated that the use of Zn fertilizers minimized Zn deficiency in plants (Kadar et al., 2003), but few scientists have associated the comparative efficacy of applying different sources of zinc to flax. Numerous statements have been made concerning the comparative efficacy of organic versus inorganic ($ZnSO_4$) zinc sources. Gangloff et al. (2002), Mostafa and El-Deeb (2003) and Bakry et al. (2012) found that the foliar application of micronutrients increases the yield and oil contents of flax.

The present study was aimed to find the effect of foliar application of zinc on yield, its components and oil contents of flax.

MATERIALS AND METHOD

The experiment was conducted at agronomic research area, University of Agriculture, Faisalabad (a semi-arid area, 31.26°N latitude and 73.06°E longitude, 184.4 m above sea level), Pakistan during winter 2012-13. The experiment was carried out to study the impact of foliar application of zinc on yield, yield components and quality of flax. The trial was laid out in randomized complete block design with three replications. The net plot size was 5m × 3.5m. Soil sampling was done before sowing of crop, according to Chapman and Pratt (1978). The soil analysis showed that the soil was sandy loam having pH, 8.20; organic matter, 0.92%; nitrogen, 0.06%; phosphorus, 5.00 ppm; potassium, 175 ppm and zinc, 0.80 ppm. Maize was harvested as a previous crop. Seed bed was prepared for flax by using 3-4 ploughing followed by 1-2 planking (planking is done to crush the hard clods to smoothen the soil surface and to compact the soil lightly). Soil was leveled by using laser land leveler. Flax was sown on November 15, 2012 by using drill with 45cm line spaced

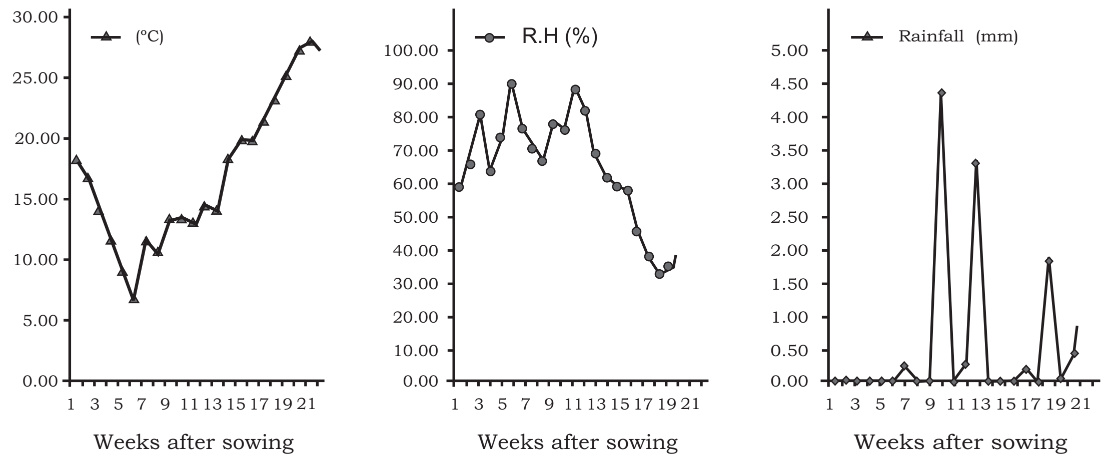

Figure 1. Weekly average temperature, relative humidity and rainfall during crop season

and plant spaced at 7 cm. Seed rate used was 20 kg ha^{-1}. Nitrogen and phosphorus fertilizer were applied @ 90 and 50 kg ha^{-1}, respectively. The entire dose of P and 1/3 dose of N was applied at sowing. While 2/3 dose of nitrogen was applied with first irrigation. Total three irrigations were applied during the growth period of the crop; 1st a week before flowering, 2^{nd} after a week of flowering and 3^{rd} at capsule formation.

Weather data (temperature, relative humidity and rainfall) during crop season was also obtained (Figure 1). All other agronomic practices were kept normal. Zinc sulphate was used as a source of zinc which was applied at bud initiation and after capsule filling. Treatments were sprayed by hand sprayer resulting smoothly wet surface area. The treatments were: Zn_0 (control), Zn_1 (0.25%), Zn_2 (0.5%), Zn_3 (0.75%), Zn_4 (1.00%), Zn_5 (1.25%), Zn_6 (1.50%), Zn_7 (1.75%), Zn_8 (2.00%), Zn_9 (2.25%), Zn_{10} (2.50%), Zn_{11} (2.75%) and Zn_{12} (3.00%). Zinc levels up to 3.00% were selected as previous studies revealed that its higher concentrations than this can adversely affects nitrogen absorption in plant which resulted in reduction in yield (Prasad, 2006). The crop was harvested at maturity on April 28, 2013. Twenty plants from each plot were collected randomly as a sample to estimate the morphological characters and seed oil contents. Crude oil in the seed was determined according to AOAC (1980). Effect of Zn on flax was analyzed on various response variables by analysis of variance (ANOVA) technique. Least significant difference test was applied to separate significantly different treatment means (Steel et al., 1997).

RESULTS AND DISCUSSION

The foliar application of Zn treatments positively affected plant height, stem length, fruiting zone length, fruiting branches, number of capsule $plant^{-1}$, number of seed $capsule^{-1}$, 1000-seed weight, seed yield, harvest index, straw yield and seed oil contents. Comparison of treatment means showed that plant height was significantly affected by the different levels of zinc. Maximum plant height (72.50 cm) was observed, when 3.00% foliar application of zinc was applied at bud initiation and after capsule filling stage (Table 1). It was statistically at par with 2.75% and 2.50% zinc (72.40 cm and 72.35 cm, respectively). However, control displayed the shortest plant height (58.18 cm). Longest stem length (61.77 cm) was found with 3.00% foliar application of zinc, followed by 2.75% zinc (60.77 cm) whereas, the smallest stem length (50.40 cm) was noted in control plot. Similarly, the largest length of fruiting zone (11.50 cm) was calculated when 3.00% zinc was sprayed and smallest length of fruiting zone (8.65 cm) was found in control. The foliar application of Zn treatments positively affected all the studied characters of flax. The zinc application increased the yield components as well as the yield of flax. This may be due to the role of zinc in the cell division, cell enlargement and synthesis of protein. Zinc also regulates the membrane function and provides resistance to environmental stress in crop plants (Cakmak, 2000). Zinc provided protection of membranes from oxidative injury by detoxification of reactive oxygen species (Marschner, 1995). Moreover, the role of zinc in biomass production is also very important (Cakmak, 2008). Zinc plays important role in increasing

Table 1. Effect of foliar application of zinc levels on growth, yield and yield components of flax

Treatment	Plant height (cm)	Stem length (cm)	Fruiting zone length (cm)	Number of fruiting branches (plant^{-1})	Number of capsule plant^{-1}	Number of seeds capsule^{-1}
Zn_0	58.18 ^{e}	50.40 ^{d}	8.65 ^{f}	3.20 ^{e}	5.16 ^{e}	6.10 ^{e}
Zn_1	60.20 ^{de}	53.80 ^{cd}	9.10 ^{ef}	3.28 ^{de}	5.30 ^{e}	6.30 ^{de}
Zn_2	61.50 ^{de}	54.75 ^{cd}	9.45 ^{def}	3.27 ^{de}	5.45 ^{de}	6.50 ^{cde}
Zn_3	62.80 ^{cde}	54.50 ^{cd}	9.80 ^{cdef}	3.32 ^{cde}	5.90 ^{cde}	6.80 ^{bcde}
Zn_4	63.10 ^{cde}	55.80 ^{bc}	10.01 ^{bcde}	3.39 ^{bcde}	6.10 ^{bcde}	7.00 ^{abcde}
Zn_5	64.00 ^{cde}	56.90 ^{abc}	10.10 ^{bcde}	3.46 ^{bcde}	6.25 ^{abcde}	7.10 ^{abcde}
Zn_6	65.20 ^{bcde}	57.65 ^{abc}	10.33 ^{abcd}	3.49 ^{abcde}	6.43 ^{abcde}	7.25 ^{abcde}
Zn_7	66.70 ^{abcd}	58.10 ^{abc}	10.65 ^{abc}	3.56 ^{abcde}	6.80 ^{abcd}	7.40 ^{abcde}
Zn_8	68.90 ^{abc}	59.80 ^{ab}	10.80 ^{abc}	3.63 ^{abcde}	7.10 ^{abc}	7.60 ^{abcd}
Zn_9	71.30 ^{ab}	60.10 ^{ab}	11.10 ^{ab}	3.70 ^{abcd}	7.36 ^{ab}	7.80 ^{abc}
Zn_{10}	72.35 ^{a}	60.33 ^{ab}	11.20 ^{ab}	3.77 ^{abc}	7.42 ^{ab}	8.00 ^{ab}
Zn_{11}	72.40 ^{a}	60.77 ^{a}	11.20 ^{ab}	3.84 ^{ab}	7.46 ^{ab}	8.36 ^{a}
Zn_{12}	72.50 ^{a}	61.77 ^{a}	11.50 ^{a}	3.95 ^{a}	7.65 ^{a}	8.40 ^{a}
LSD 5%	7.13	4.62	1.19	0.47	1.45	1.49

Means followed by same letter do no differ significantly at P = 0.05 level plant height, number of capsule and branches and seed yield (Bakry et al., 2012). Therefore, the increase in plant height, stem length and length of fruiting zone may be because of zinc, which play a role in the biosynthesis of the protein and oil (Omidian et al., 2012), cell membrane integrity and in plant metabolism.

The largest number of fruiting branches (3.95 plant^{-1}) were attained with 3.00% zinc sprayed and the lower number of fruiting branches (3.20 plant^{-1}) were observed in control plot. Likewise, the higher number of capsule (7.65 plant^{-1}) was found when 3.00% zinc was sprayed at bud initiation and after capsule filling stage, followed by 2.75% zinc application (7.46 plant^{-1}). However, control displayed the minimum number of capsule (5.16 plant^{-1}). The foliar spray of zinc increases the number of fruiting branches plant^{-1} and number of seed capsule^{-1} (Bakry et al., 2012). This may be due to the involvement of zinc in photosynthesis, for chlorophyll production, pollen function and fertilization (Pandey et al., 2006).

Similar results were found in number of seeds capsule^{-1}. The 3.00% foliar application of zinc exihibited the maximum number of seeds (8.40 capsule^{-1}), followed by 2.75% zinc (8.36 capsule^{-1}). Minimum number of seeds (6.10 capsule^{-1}) were observed in control plot. The data on 1000-seed weight elucidated that the 3.00% foliar application of zinc at bud initiation and after capsule filling stage attained heaviest 1000-seed weight (7.85 g), followed by 2.75% and 2.50% zinc (7.80 g and 7.72 g, respectively), and control plot displayed minimum 1000-seed weight (5.02 g) (Table 2). Application of zinc enhances the lateral shoots, which helps for more capsules. Moreover, zinc maximizes the biosynthesis of growth hormone, starch formation and maturation, so, it ultimately increased the seed weight. The foliar application of zinc on flax increased the 1000-seed weight (El-Sweify et al., 2006). The increase in 1000-grain weight of crop plants might be due to zinc that has high phloem mobility from leaves to roots, stem and developing grains (Rengel, 2001).

Comparison of treatment means showed that seed yield was significantly affected by the different level of zinc (Table 2). Maximum grain yield (1050 kg ha^{-1}) was found when 3.00% foliar application of zinc was applied at bud initiation and after capsule filling stage and minimum (550 kg ha^{-1}) was observed in control plot. Similarly, maximum straw yield plant^{-1} (3625 kg ha^{-1}) was found with 3.00% foliar application of zinc applied at bud initiation and after capsule filling stage and minimum (2500 kg ha^{-1}) was found in control where nothing was applied. Saedi (2002) stated that the foliar application of zinc promoted the vegetative and flowering stage due to increase in the plant metabolism and photosynthesis. This increase in flax yield may be due to the abundant efficacy of enzyme activities which influence plant pigments because zinc is an important component of all classes of enzymes (CIMMYT, 2000 and Malakouti, 2007). In this concern, Babaeian et al. (2011) stated that zinc has favorable effects on the metabolism of plant which might be responsible for greater metabolite

Table 2. Effect of foliar application of zinc levels on yield, yield components and oil content of flax

Treatments	1000 seed weight (g)	Straw yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest Index (%)	Seed oil (%)
Zn_0	5.02 ^{e}	2500 ^{m}	550 ^{j}	22.00 ^{fg}	34.00 ^{e}
Zn_1	5.37 ^{de}	2750 ^{l}	600 ^{i}	21.82 ^{g}	34.20 ^{de}
Zn_2	5.42 ^{de}	2875 ^{k}	650 ^{h}	22.61 ^{efg}	34.40 ^{cde}
Zn_3	5.48 ^{de}	2925 ^{j}	675 ^{gh}	23.08 ^{ef}	34.75 ^{bcde}
Zn_4	6.05 ^{cde}	2975 ^{i}	700 ^{g}	23.53 ^{e}	35.05 ^{abcde}
Zn_5	6.23 ^{bcde}	3025 ^{h}	750 ^{f}	24.79 ^{d}	35.40 ^{abcde}
Zn_6	6.28 ^{abcde}	3075 ^{g}	800 ^{e}	26.02 ^{c}	35.72 ^{abcde}
Zn_7	6.80 ^{abcd}	3125 ^{f}	825 ^{e}	26.40 ^{c}	35.96 ^{abcd}
Zn_8	7.35 ^{abc}	3175 ^{e}	875 ^{d}	27.56 ^{b}	36.26 ^{abc}
Zn_9	7.55 ^{abc}	3325 ^{d}	925 ^{c}	27.82 ^{b}	36.53 ^{ab}
Zn_{10}	7.72 ^{ab}	3550 ^{b}	1000 ^{b}	28.17 ^{ab}	36.40 ^{ab}
Zn_{11}	7.80 ^{ab}	3500 ^{c}	975 ^{b}	27.86 ^{b}	36.65 ^{a}
Zn_{12}	7.85 ^{a}	3625 ^{a}	1050 ^{a}	28.97 ^{a}	36.78 ^{a}
LSD 5%	1.57	32.28	29.81	1.07	1.87

accumulation in the reproductive organs. Mohsen et al. (2009) also suggest that foliar spray of Zn and Mn increased the seed yield of safflower (*Carthamus tinctorius L.*). Similarly, foliar application of zinc sulfate significantly improved the seed yield of canola (*Brassica napus*) (Omidbeigi, 2005), safflower (*Carthamus tinctorius L.*) (Movahedy et al., 2009), lentil (*Lens culinaris*) (Nakhzari et al., 2011) and soybean (*Glycine max*) (Jamson et al., 2009).

More the harvest index more will be the seed yield. Maximum harvest index (28.97%) was found with 3.00% foliar application of zinc, followed by 2.75% zinc (28.86%) and minimum harvest index (22%) was found in control where no zinc was applied (Table 2). Zinc also increased straw yield by increasing biomass production (Cakmak, 2008). Zinc may enhance seed yield and biological yield, which directly enhanced harvest index.

Seed oil percentage was increased significantly by foliar spray of zinc element on flax plants (Table 2), maximum oil percentage (36.78 %) in seed was found when 3.00% foliar application of zinc was applied at bud initiation and after capsule filling stage, followed by 2.75% zinc (36.65%) and minimum value (34%) was found in control plot where no zinc was applied. Zinc is a very important element in the synthesis of protein and oil biosynthesis in seeds (Omidian et al., 2012). It has been reported that application of zinc on flax led to maximum growth rate and oil percentage (Nofal et al., 2001).

It is therefore, concluded that the foliar application of Zn treatments positively affected all the studied characters of flax. However, foliar application of zinc (3.00%) at bud initiation and after capsule filling stage of flax is the most suitable and beneficial to increase the production potential of flax under the agro-ecological conditions of Faisalabad, Pakistan. In this experiment, the higher dose of zinc (3.00% at bud initiation and after capsule filling stage of flax) provided best results..

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