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Yield and Yield Components of Three Flax Cultivars (*Linum usitatissimum* L.) In Response to Foliar Application with Zn, Mn and Fe under Newly Reclaimed Sandy Soil Conditions

B.A. Bakry, M.M. Tawfik, B.B. Mekki and M.S. Zeidan

Department of Field Crop Research, National Research Centre, Dokki, Giza, Egypt

Abstract: Two field experiments were conducted at the Research and Production Station, National Research Centre, El-Nubaria Province, El-Behira Governorate, Egypt, during the two successive winter seasons of 2010/2011 and 2011/2012 to study the response of yield and yield components of three flax cultivars (Giza 8, Olin and Amon) to foliar application with Zn, Mn and Fe. The results revealed high significant differences among the flax genotypes in yield and its components. Giza 8 cultivar surpassed Olin and Amon cultivars in the characters of plant height (cm), technical length(cm), 1000-seed weight (g), straw yield (t/ha), fiber % and fiber yield (t/ha), while Olin cultivars produced the highest values of seed yield/ plant (g). On the other hand, Amon cultivar surpassed the other two cultivars in fruiting zone length (cm), number of branches/plant, number of capsules/plant, straw yield/plant (g), seed yield (t/ha), harvest index, oil % and oil yield (t/ha). Foliar application with Zn, Mn or Fe positively affected all the studied characters compared with control treatment with superiority to Zn over the other micronutrients. Yet, the combined application of three micronutrients was to some extent, much more effective. Yield and yield attributes and also seed oil % are significantly affected by the interaction between cultivars and foliar application with Zn, Mn and Fe. Therefore, it can be concluded that, the foliar application of Zn, Mn and Fe had positive effect on oil and fiber yields of flax plants. In general the flax cultivars were significantly different in their seed and oil yields due to application of these micronutrients as combined treatment. The highest seed and oil yields (1.574 and 0.637 t/ha, respectively) were recorded in Amon cultivar received Zn+ Mn+Fe as one treatment, while Giza 8 cultivar produced the highest fiber yield (1.289 t/ha) under the same foliar application treatment.

Key words: Flax cultivars · Foliar application · Zn · Mn and Fe · Growth · Yield and yield attributes

INTRODUCTION

Flax (*Linum usitatissimum* L.) is an old economic crop grown as a dual purpose crop for seeds and fibers which is used for the manufacture of linen. The oil is edible and also, due to its quick dyeing properly is used for the preparation of paints, varnishes, printing ink, oil cloth and soap. In Egypt, flax plays an important role in the national economy owing to export beside local industry. Increasing the production of flax could be achieved through growing high yielding genotypes and proper fertilizer application. Flax is the second fiber crop after cotton in Egypt with regard to the cultivated area and economic importance [1]. Nowadays, the benefits of flax have passed all expectations. Regardless the well-known ordinary uses, the crop has more benefits in producing feeding stuff for animals and poultry and moreover in producing some kinds of compact wood, popular in name particle board. The crop is also popular in several fine industries in which making electric insulations and non-textile medical materials are the most important. More valuable is that related to producing bank note papers. Flax cultivars significantly differed in yield and its attributes as well as oil content [2, 3]. In this concern, Sharief [4] reported that Liflora cultivar surpassed other four cultivars in plant height, technical length, 1000-seed weight and straw yield. Moreover, Sharief *et al*. [5] stated that Giza 8 cv. surpassed Blanka in number of fruit branches/plant, number of capsules/plant, 1000-seed weight, weight of seeds/plant as well as seed

Corresponding Author: B.A. Bakry, Department of Field Crop Research, National Research Centre, Dokki, Giza, Egypt.

and straw yields/ha, while Blanka surpassed Giza 8 in plant height, technical length and straw yield. One of the important approaches is the use of foliar application for increasing flax production. The effect of micronutrient elements on yield and crop performance has been reported by Nasiri *et al.* [6]. They also added that, iron (Fe) enters many plant enzymes that play dominant roles in oxidoredox reactions of photosynthesis and respiration, manganese (Mn), in turn, is regarded as an activator of many different enzymatic reactions and takes part in photosynthesis while zinc, is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes. Moreover, Marschner [7] stated that, micronutrients, especially Fe and Zn, act either as metal components of various enzymes or as functional, structural, or regulatory cofactors. Thus, they are associated with saccharide metabolism, photosynthesis, nucleic acid, lipid metabolism and protein synthesis. Who added that, zinc is an essential micronutrient for synthesis of auxin, cell division and the maintenance of membrane structure and function. Zinc also plays an important role in the production of biomass [8] and chlorophyll production [9].

The objective of the present investigation is, therefore, to study the impact of foliar application with Zn, Mn and Fe on yield and yield components of three flax cultivars grown under newly reclaimed sandy soil as it is considered one of the most economic important crops in Egypt.

MATERIALS AND METHODS

Two field experiments were conducted at the Research and Production Station, National Research Centre, El-Nubaria Province, El-Behira Governorate, Egypt, during the two successive seasons of 2010/2011 and 2011/2012 to study the response of yield and yield attributes of three flax cultivars (Giza 8, Oline and Amone) to foliar application with Zn, Mn and Fe singly or combined in one treatment Zn + Mn +Fe by using zinc sulphate, manganese sulphate and ferrous sulphate at the concentration of 0.35% for all micronutrients. Each field experiment was laid out in split plot design in three replications. The experimental plot area was 10.5 m^2 (3.5 meters long and 3.0 meters width). Phosphorus fertilizer was added before sowing at the rate of 72 kg/ha as ordinary calcium superphosphate (15.5% P_2O_5), while potassium was added at the rate of 60kg/ha as potassium sulphate (48 % K_2O). Nitrogen fertilizer was

Table 1: Physical and chemical analysis of the experimental sites (Average values of 2010/2011 and 2011/2012 seasons).

Variables	Values
Clay %	7.20
Sand %	88.80
Silt %	4.00
Soil texture	Sandy
pH	8.83
Ec (dS/m)	0.32
HCO_3 %	4.58
OM %	0.24
P (mg/100 g soil)	0.24
K (mg/100 g soil)	0.82
Na (mg/100 g soil)	12.36
Ca (mg/100 g soil)	92.00
Mg (mg/100 g soil)	18.40
Zn (ppm)	0.13
Fe (ppm)	5.92
Mn (ppm)	4.34

applied at the rate of 180 kg/ha in the form of ammonium nitrate (33.5 % N) in three equal portions (20 days after sowing, before second irrigation and at flowering stage). Sowing took place at 1st November in both seasons for all flax cultivars. Seeds with seeding rate of 144 kg/ha were hand drilled in rows 15 cm apart. Seeds of flax were obtained from Prof. El- Hariri, NRC, Field Crops Res. Dept. Giza, Egypt. Physical and chemical analysis of soil site is presented in Table 1 as described by Page *et al.* [10]. At full maturity stage (middle of May), ten guarded plants were taken at random from each sub plot to estimate plant height (cm), technical stem length (cm), number of fruiting branches/plant, numbers of capsules /plant and seed and straw yields/plant (g). Seed and straw yields (t/ha) were estimated from the central area of one square meter of each sub plot. Plants were harvested, tied and left to dry, capsules were removed carefully to determine straw yield and then converted to straw yield in (t/ha). Seeds were cleaned from straw and other residuals and weighed to the nearest gram and converted to record seed yield (t/ha) and then straw retting was carried out at Tanta Flax and Oil Company using warm water retting system under controlled condition (30-35°C). Seed oil % was determined by using Soxhlet apparatus and petroleum ether (40-60°C) as a solvent according to A.O.A.C. [11]. Oil yield (t/ha) was calculated by seed yield (t/ha) x seed oil (%). Fiber percentage was calculated by (weight of total fiber (g) /weight of straw after retting (g)) x 100. Fiber yield (t/ha) was calculated by straw yield (t/ha) x fiber (%). Harvest index was calculated by seed yield (t/ha)/biological yield (t/ha) x 100.

Statistical Analysis: The obtained results were subjected to statistical analysis of variance according to method described by Snedecor and Cochran [12] since the trend was similar in both seasons the homogeneity test Bartlet's equation was applied and the combined analysis of the two seasons was calculated according to the method of Steel and Torrie [13].

RESULTS AND DISCUSION

Performance of Different Flax Cultivars: Data presented in Table 2 revealed high significant differences among the flax genotypes in yield and its components. Giza 8 cultivar surpassed Olin and Amon cultivars in plant height (cm), technical length(cm), 1000-seed weight (g), straw yield(t/ha), fiber % and fiber yield (t/ha), while Amon cultivar produced the highest values of seed yield(t/ha). Also, the same cultivar surpass the other two cultivars in fruiting zone length (cm), number of branches/ plant, number of capsules/ plant, straw yield/plant (g), harvest index, oil % and oil yield (t/ha). The differences between the tested cultivars mainly attributed to the differences in their genetical constitution and their response to the environmental conditions. Such results are in harmony with those obtained by El-Sweify *et al.* [14] and Abd El-Fatah [15]. Also, the differences between cultivars (Table 2) may be due to the differences in other yield attributes i.e. number of capsules/plant, 1000-seed weight and seed yield/plant. Data presented in Table 2 also indicated that Giza 8 (local variety) produced the highest values of fibre % (14.04) and also fibre yield (1.156 t/ha) in comparison to the other two exotic cultivars Olin and Amon. Such increases in these traits mainly due to the increase of plant height and technical length of Giza 8 than other two cultivars. Similar results are in agreement with those obtained by El-Hariri *et al.* [1], El-Shahawy *et al.* [3], Sorour *et al.* [16], Khalifa *et al.* [17] and Bakry *et al.* [18]; they reported that the flax cultivars differed in seed yield productivity. These results indicated that the variability among tested flax varieties which may be expected due to the differences of these varieties in origin, growth habit, the high diversity in genetic constituent and the environmental conditions of investigated cultivars under newly reclaimed sandy soil.

Effect of Foliar Application with Micronutrients: Data presented in Table 3 indicated that foliar spraying with Zn, Mn or Fe as sole treatment positively affected all the studied characters of flax plants; however application of Zn singly increased the growth characters as well as yield and yield components of flax plants in comparison to application of Mn or Fe as sole treatment. The results of increasing in seed yield and most of yield components would find an interpretation through that foliar application in equal ratio of micronutrients compound (3% Fe+ 3% Mn+ 3% Zn) could cover at least considerable part of genotype nutritive needs and through affecting the metabolic processes of plant growth was enhanced [19]. For instance the role of Zn in biosynthesis of natural auxin indole acetic acid. Moreover, Mn activates number of enzymes involved in carbohydrate synthesis and also essential in the photo system II. Also, Fe acts as a catalyst chlorophyll formation [20] and improves the photosynthesis processes, leading to more dry matter production.

Table 2: Performance of different flax (*Linum usitatissimum* L.) cultivars. (Combined analysis of 2010/2011 and 2011/2012 seasons)

	Cultivars			
Characters	Giza 8	Olin	Amon	LSD 0.05
Plant height (cm)	82.29	63.89	74.02	0.99
Technical length (cm)	63.07	43.9	53.23	0.87
Fruiting zone length (cm)	19.22	19.99	20.79	0.87
No. of branches/plant	5.06	4.92	5.57	NS
No. of capsules/plant	13.83	13.19	15.39	0.88
Seed yield/plant (g)	0.93	0.95	0.93	NS
Straw yield/plant (g)	1.65	1.40	1.71	0.06
1000-seed weight (g)	8.45	6.38	5.38	0.08
Seed yield (t/ha)	1.315	1.425	1.497	0.046
Straw yield (t/ha)	8.232	6.768	6.792	0.360
Harvest index	13.77	17.39	18.06	0.02
Oil %	37.86	37.9	39.13	0.13
Oil yield (t/ha)	0.498	0.540	0.586	0.029
Fiber %	14.04	12.31	12.01	0.20
Fiber yield (t/ha)	1.156	0.833	0.816	0.015

Table 3: Effect of foliar feeding with Zn, Mn and Fe on yield and yield attributes of flax. (Combined analysis of 2010/2011 and 2011/2012seasons)

	Foliar application treatments				
Characters	Zn	Mn	Fe	Zn +Mn+ Fe	LSD 0.05
Plant height (cm)	82.70	69.00	73.10	76.85	1.14
Technical length (cm)	62.90	50.60	53.08	55.78	1.01
Fruiting zone length (cm)	19.80	18.40	20.02	21.07	1.00
No. of branches/plant	5.12	4.78	5.13	5.55	NS
No. of capsules/plant	14.00	12.03	13.88	15.93	1.02
Seed yield/plant (g)	0.94	0.81	0.90	1.09	0.04
Straw yield/plant (g)	1.65	1.50	1.57	1.69	0.07
1000-seed weight (g)	8.45	6.62	6.72	6.86	0.09
Seed yield (t/ha)	1.303	1.370	1.399	1.465	0.053
Straw yield (t/ha)	8.280	6.816	7.200	7.656	0.048
Harvest index %	13.60	16.74	16.27	16.06	0.22
Oil %	38.10	37.44	38.18	39.17	0.26
Oil yield (t/ha)	0.496	0.513	0.534	0.575	0.016
Fiber %	13.90	12.16	12.72	13.43	0.21
Fiber yield (t/ha)	1.151	0.834	0.921	1.037	0.027

Table 4: Effect of interaction between foliar feeding with micronutrient and different flax cultivars (Combined analysis of 2010/2011 and 2011/2012seasons)

Varieties	Giza 8				Olin				Amon				
Characters	Zn	Mn	Fe	Zn+ Mn + Fe	Zn	Mn	Fe	Zn+ Mn + Fe	Zn	Mn	Fe	Zn+ Mn + Fe	LSD 0.05
Plant height (cm)	82.70	79.30	81.85	85.30	64.10	61.95	63.75	65.75	77.11	65.75	73.69	79.50	2.33
Technical length (cm)	62.90	61.43	62.35	65.60	43.60	43.14	44.12	44.75	55.89	47.24	52.77	57.00	2.06
Fruiting zone length (cm)	19.80	17.87	19.50	19.70	20.50	18.81	19.63	21.00	21.22	18.51	20.92	22.50	NS
No. of branches/plant	5.12	4.86	4.95	5.30	5.00	4.61	4.95	5.10	5.65	4.86	5.50	6.25	0.02
No. of capsules/ plant	14.00	12.00	13.61	15.70	14.25	10.76	12.88	14.85	15.83	13.33	15.15	17.23	1.03
Seed yield/ plant (g)	0.94	0.82	0.91	1.03	0.96	0.86	0.92	1.07	0.92	0.75	0.87	1.17	0.07
Straw yield/plant (g)	1.65	1.56	1.67	1.73	1.43	1.31	1.37	1.50	1.70	1.62	1.66	1.85	0.01
1000 - seed weight (g)	8.45	8.33	8.49	8.53	6.44	6.22	6.35	6.50	5.35	5.30	5.33	5.55	0.12
Seed yield (t/ha)	1.303	1.292	1.319	1.345	1.430	1.381	1.414	1.476	1.513	1.437	1.465	1.574	0.108
Straw yield (t/ha)	8.280	7.848	8.201	8.568	6.912	6.410	6.622	7.104	6.900	6.168	6.756	7.320	0.350
Harvest index %	13.60	14.14	13.86	13.57	17.14	17.73	17.60	17.20	17.98	18.90	17.82	17.70	0.13
Oil %	38.10	37.00	38.50	37.85	38.00	37.11	37.33	39.15	39.10	38.22	38.71	40.50	0.19
Oil yield (t/ha)	0.496	0.478	0.508	0.509	0.543	0.512	0.528	0.578	0.591	0.549	0.567	0.637	0.011
Fiber %	13.90	13.25	13.95	15.05	12.46	11.71	12.31	12.75	12.10	11.53	11.89	12.50	0.15
Fiber yield (t/ha)	1.151	1.040	1.144	1.289	0.861	0.751	0.815	0.906	0.835	0.711	0.803	0.915	0.020

So far, the results obtained were also coincided with those obtained by El-Shahawy *et al.* [3]. The increase in seed yield with zinc foliar application may be attributed to the fact that zinc is necessary for root cell membrane integrity [21]. Moreover, zinc plays an important role in the production of biomass [8]. Furthermore, zinc may be required for chlorophyll production, pollen function and fertilization [22]. In addition, zinc or manganese is involved in membrane protection against oxidative damage through the detoxification of reactive oxygen species [7]. In this regard, Babaeian *et al*. [23] reported that, Zn is required in the synthesis of tryptophan, which is a precursor in t he synthesis of indole-3-acetic acid (a hormone that inhibits abscission of squares and bolls). They also added that, this nutrient has favorable effects on the photosynthetic activity of leaves and plant metabolism which might account for higher accumulation of metabolites in reproductive organs (bolls). Moreover, they have essential roles in plant metabolism [24]. The positive impact of Mn treatment resulted from the fact that manganese (Mn) is regarded as an activator of many different enzymatic reactions and takes part in photosynthesis. Mn activates decarboxylase and dehydrogenase [25]. Subsequent experiments have proved the reliability of iron on increasing growth and yield productivity of flax including oil and fiber quality [17, 26]. Iron plays essential roles in the metabolism of chlorophylls and it enters in many plant enzymes that play dominant roles in oxidoredox reactions of photosynthesis and respiration. External application of Fe increased photosynthesis, net assimilation and relative growth in plants [27].

Interaction Effect Between Foliar Application with Micronutrients and Flax Cultivars: All studied characters were significantly affected by the interaction between cultivars and foliar application with Zn, Mn and Fe, except fruiting zone length was not significantly affected (Table 4). The same table indicated that foliar spraying with Zn, Mn or Fe positively affected yield and yield attributes with superiority of Zn application over the other micronutrients in the three cultivars. Moreover, the combined Zn+ Mn +Fe in one treatment increased growth and yield and its attributes compared with the application of three micronutrients singly. The highest values of seed and oil yields (t/ha) were recorded in Amon cultivars sprayed with Zn+ Mn +Fe as one treatment, while Giza 8 cultivar produced the highest fiber yield (1.289 t/ha) when received Zn+ Mn+ Fe singly (Table 4). In this regard, Nasiri *et al.* [6] reported that, micronutrients, especially Fe and Zn are associated with saccharide metabolism, photosynthesis and protein synthesis. They also added that, Fe has important functions in plant metabolism, such as activating catalase enzymes associated with superoxide dismutase, as well as in photorespiration, the glycolate pathway and chlorophyll content. Micronutrients play a great part in plant growth, although of its small needed by the plants. It is entering in many critical positions of managing growth and development within the plants. Of those especially of our concern (Zn, Mn and Fe), they are considered a basic part of several enzymes that control redox reactions within the plants [20]. They are also essential for plant metabolism of carbohydrates, proteins, phosphate, RNA, chlorophyll synthesis, nucleic acid biosynthesis and ribosome formation [7]. In addition to their valuable role as precursors of several phytohormones. Moreover, Ghasemian *et al.* [28] proved that, iron plays essential roles in the metabolism of chlorophylls, increased photosynthesis, net assimilation and relative growth.

CONCLUSION

Micronutrients specially zinc are very important elements for growth and yield of flax plants. The results of this study demonstrated that, foliar application with Zn +Mn+Fe had positive effect on seed, oil and fiber yields of flax plants. Combined application of these nutrients increased some growth and yield characters in comparison to single application of these micronutrients. Moreover, it was noticed that the flax cultivars was differed in their response to foliar micronutrients treatments. The highest values for seed and oil yields (t/ha) were recorded with Amon cultivar sprayed with Zn+ Mn+Fe, while Giza 8 cultivar produced the highest fiber yield (t/ha) under the same treatment.

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